DOCUMENT RESUME

ED 192 084 CE 026 642

TITLE	Nuclear Technology Series. Nuclear Quality-Assurance and Quality-Control Technician. A Suggested Program Planning Guide. Revised June 80.
INSTITUTION	Center for Occupational Research and Development, Inc., Waco, Tex.: Technical Education Research Center, Waco, Tex.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	Jun 80
CONTRACT	300-78-0582
NOTE	72p.: For related documents see CE 026 639-672, CE 026 779-780, CE 026 782-785, and CE 026 855-856.
AVAILABLE FROM	Center for Occupational Research and Development, 4800 Lakewood Dr., Suite 5, Waco, TX 76710 (Modules are available individually or by course; write for prices)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Learning Modules; *Nuclear Energy; Postsecondary Education; *Program Development; Program Guides; *Quality Control; *Technical Education; Technical Occupations
IDENTIFIERS	*Nuclear Energy Occupations; Nuclear Power Plants; Nuclear Technology

ABSTRACT

This program planning guide for a two-year postsecondary nuclear quality-assurance and quality-control technician program is designed for use with courses 26-32 of thirty-five in the Nuclear Technology Series. The purpose of the guide is to describe the nuclear power field and its job categories for specialists, technicians and operators; and to assist planners, administrators, faculty, and industrial and community educational advisors in establishing and conducting relevant training programs. The guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing, and instructional materials needed for training technicians and operators in this field. Appended material includes the technical specialty courses and module titles and descriptions; suggested workforce needs survey instrument for nuclear quality-assurance/quality-control technicians; equipment list with cost, quantity, and vendor data; and suggested library references and materials. (A master index to the series and other suggested program planning guides are available--see CE 026 856 and CE 026 639-643.) (LRA)

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NUCLEAR TECHNOLOGY SERIES

NUCLEAR QUALITY-ASSURANCE AND QUALITY-CONTROL TECHNICIAN

A SUGGESTED PROGRAM PLANNING GUIDE

(REVISED JUNE 80)

CE 026 642

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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Developed pursuant to Contract #300780582
by the Technical Education Research Center — Southwest
Waco, Texas
Funded by the United States Office of Education under
Part I, Curriculum Development in Vocational and Technical
Education, Vocational Education Amendments of 1968,
Public Law 90-576
1977

The Nuclear Technology Series consists of five curricula (see page 2).

Nuclear Quality Assurance/Quality Control Technician.
Nuclear Reactor (Plant) Operator Trainee.
Radiation Protection Technician.
Nuclear Materials Processing Technician.
Nuclear Instrumentation and Control Technician.

The Nuclear Quality Assurance/Quality Control Technician curriculum consists of the following 15 technical specialty courses made up of 116 instructional modules (see Appendix B for module titles and descriptions):

Radiation Physics.
Radiation Protection I.
Principles of Process Instrumentation.
Introduction to Nuclear Systems.
Radiation Detection and Measurement.
Introduction to Quality Assurance/Quality Control.
Metallurgy and Metals Properties.
Mechanical Component Characteristics and Specifications.
Nondestructive Examination (NDE) Techniques I.
Metrology.
Welding Inspection.
Civil/Structural Inspection.
Mechanical Inspection.
Quality-Assurance Practices.
Nondestructive Examination (NDE) Techniques II.

Availability: Instructional modules are available individually or by courses from:

Center for Occupational Research and Development
4800 Lakewood Drive
Waco, Texas 76710

FOREWORD

In response to the needs of the nuclear power industry, a curriculum has been designed and 116 instructional modules have been developed. These modules may be used by two-year, post-secondary technical institutions to train men and women to work as nuclear quality-assurance and quality-control technicians. The instructional materials also are useful to employers for training or updating their employees in company-sponsored educational programs.

The purpose of this Guide is to describe the nuclear power field and its job categories for specialists, technicians and operators, and to assist planners, administrators, faculty and industrial and community educational advisors in establishing and conducting relevant training programs.

The Guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing and instructional materials needed for training technicians in this field. This information is based on task inventories conducted by the Center for Occupational Research and Development staff and on the collective thinking of the National Steering Committee for Nuclear Technician Training, made up of employers, technical specialists and educators.

Funds for this project were provided under contract from the U. S. Office of Education, Bureau of Adult and Occupational Education, Mr. William M. Berndt, Project Officer. Additional assistance in the form of valuable advice, encouragement and guidance was provided by Dr. Walter J. Brooking, Project Monitor.

ACKNOWLEDGMENTS

The staff of the Center for Occupational Research and Development wishes specifically to acknowledge the valuable contributions made to this project by three groups. First, a special thanks goes to the two project advisors.

Dr. Maurice W. Roney, Texas State Technical Institute.

Mr. W. Scott Fellows, Director of Special Programs,
Southern States Energy Board.

Second, the invaluable assistance of a dedicated National Steering Committee for Nuclear Technician Training merits special acknowledgment: the members of this committee are listed in Appendix A.

Thirdly, the quality and relevance of this curricula and the instructional materials owe much to the technical resource personnel, writers, module reviewers, and editors too numerous to identify by name but who must be recognized in their entirety.

Staff members of the Center for Occupational Research and Development who have contributed significantly to this entire project and to the materials contained in this guide include:

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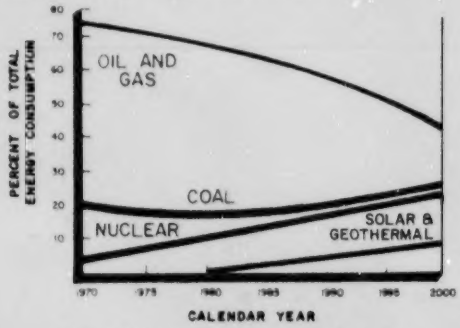
NUCLEAR TECHNOLOGY

Nuclear fission -- atom splitting -- generates heat, providing an energy source for electrical plants. Its world-wide impact is rapidly increasing. At the beginning of 1980, 67 on-line nuclear-fueled plants provided 13 percent of America's electrical power. By 2000, this percentage will have doubled. And outside the United States, nations on nearly every continent are looking to nuclear fission for electrical power generation.



Projected consumption of various energy sources.

Indeed, nuclear reactors have come of age in the electrical power generating industry. Genuine concerns, embodied in laws and regulations, have required nuclear technology to be among the safest and cleanest processes available for electrical power generation.

Today, nuclear technology, once recognized for only its destructive ability, has become a multipurpose field of endeavor, providing many human services and offering ar array of new technical career opportunities.

CAREERS IN NUCLEAR TECHNOLOGY

As a technology, the nuclear field has passed the state of basic research through the phase of applied research and into an era of practical application. The first commercial nuclear electrical power plant (Shippingport, Pennsylvania) came on-line in 1958. But nuclear fission had already proved its capability as a virtually limitless and inexhaustible power source aboard the submarine, USS Nautilus -- this first nuclear powered vessel began its sea trials in 1955. Many of industry's early nuclear operators and technicians were former seamen from the Navy's extensive nuclear fleet.

The world's first nuclear-powered vessel, the USS Nautilus.

Today, a few technical-vocational schools offer limited nuclear programs. But industry's ability to absorb trained technicians with nuclear skills is barely affected by graduates of these programs. Ingress into industry from the Navy has dwindled to an ineffective trickle.

Recent workforce needs assessments, made and supported by a strong National Steering Committee (Appendix A) composed of employers of nuclear operators and technicians, identified a present (1977) need in industry for half a million people with nuclear skills and knowledge. Also, five major technical occupations in or directly related to electrical power plant/nuclear reactor operation were identified:

Quality Assurance/Quality Control Technician.

Nuclear Reactor (Plant) Operator Trainee.

Radiation Protection Technician.

Nuclear Materials Processing Technician.

Nuclear Instrumentation and Control Technician.

The major emphasis of this Guide is preparation of Nuclear Quality Assurance/Quality Control Technicians. The educational material described herein offers nuclear-option curricula for individuals working with radioactive materials in each of the five technical occupations. Therefore, a general job description of each of these major technician classifications associated with power plants is included, along with a brief mention of other opportunities in nuclear technology.

Key
- ● Operable
- ○ Under Construction
- ◘ Limited Work Authorizations
- ▲ On Order

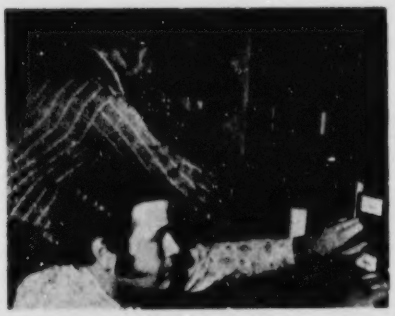
72	Reactors with operating licenses	52,398 MWe
92	Reactors with construction permits	101,148 MWe
4	Reactors with limited work authorizations	4,112 MWe
30	Reactors on order (including 4 units not sited on map)	35,082 MWe
198	Total	192,738 MWe

Nuclear electrical power plant distribution, December 31, 1978.
(Courtesy U.S. Atomic Forum.)

QUALITY ASSURANCE/QUALITY CONTROL TECHNICIAN

Quality assurance (QA) and quality control (QC) consists of testing, inspecting and auditing materials, equipment and processes to ensure that all are maintained within specified qualitative and quantitative limits.

The QA/QC technician may conduct non-destructive testing of materials or use other methods for inspecting materials and workmanship for compliance with regulations and specifications. Duties may include electrical, civil, mechanical and welding inspection of equipment, materials, processes and structures during construction, operation and maintenance of a power plant.



Trained QA/QC technicians ensure quality materials and workmanship.

Quality assurance and quality control are required in three phases: (1) the design and procurement phase, (2) the construction phase, and (3) the operation phase. Extensive records must be maintained during each of the phases.

Almost every new technology represents a potential hazard to human environment. The more advanced the technology, the more dangerous its adverse effects and consequences, unless there are adequate safeguards. These safeguards the public cannot directly provide; safeguards are the responsibility of those who control the development and application of technology. In the case of nuclear facilities, a high degree of reliability is required to assure the public that there is no undue risk to health and safety. These and similar conditions have fostered and propagated the regulatory-agency concept.

From the standpoints of product reliability, adequacy of safeguards, protection of the environment, and the like, one might ask, "What are the normal causes of shortcomings?" These have been categorized in many ways. One set of causes frequently referred to includes incomplete specifications and procedures (relates to experience also); insufficient planning, poor communications, lack of training (key factor at all levels); inadequate tools and equipment; and lack of attention (an attitude and motivation problem).

Complex nuclear facilities are being designed, built, and operated to meet specific cost, reliability, and safety standards. This positive performance has resulted in part from an attitude of quality consciousness among nuclear personnel. Quality-assurance/quality-control technicians must ensure that every facility is checked out thoroughly before it goes on line and that it continues to operate safely and efficiently.

A comprehensive system of planned and documented audits must be carried out to verify compliance with all aspects of quality-assurance programs. The audits must be performed in accordance with written procedures or checklists by appropriately-trained personnel not having direct responsibilities in the areas being audited. Audit results are documented and reviewed by management having responsibility in the area audited. Responsible management must take necessary action to correct any deficiencies revealed by the audit.

Audits should be performed to provide an objective evaluation of compliance with established requirements, methods and procedures; to assess progress in assigned tasks; to determine adequacy of quality assurance program performance; and to verify implementation of recommended corrective action. Deficient areas should be re-audited until corrections have been accomplished.

Thorough audits include an evaluation of quality-assurance practices, procedures and instructions; effectiveness of implementation; and conformance with policy directives. In performing this evaluation, the audits should include evaluation of work areas, activities, process and items, and review of documents and records.

Expanding use of nuclear power in generation of electricity, as well as in production of nuclear components in industry, requires the Nuclear Regulatory Commission (NRC) to ensure that its regulations include quality-assurance criteria as found in Appendix "B," Title 10, CFR50 (Code of Federal Regulations, Part 50). The terms, quality assurance (QA) and quality-assurance criteria (QAC), for nuclear power plants, were introduced to the industry for the first time in April, 1969.

Quality-assurance criteria mandate that every applicant for a nuclear facility construction permit, or an operating permit, include in its application a description of the quality-assurance program to be applied to the following areas: (1) design, (2) fabrication, (3) construction, (4) testing, and (5) operation.

The quality-assurance program must include information pertaining to managerial and administrative controls for safe operation of the facility. This requirement protects the health and safety of the public.

Quality control (QC) is that part of quality assurance covering actions taken to check, test or verify that skills and techniques of workmanship included in the making of products meet pre-established physical characteristics. Quality assurance complements quality control by taking actions to record and document that quality-controlled products will perform satisfactorily in service.

In recent years, the utilities have established company or contractor training centers, providing curricula that correlate with on-the-job training to prepare individuals to become QA/QC technicians. These training centers have produced the desired results, but at excessive costs to the utilities – costs that must eventually be borne by the public.

Now, the technical preparation for QA/QC technicians can be provided by post-secondary, two-year, vocational/technical schools. The modular curriculum materials described in this Guide cover this application. They can also be applied to technical preparation as presented by the training centers and in retraining activities conducted for or within the utilities.

As reiterated on page 6, these curriculum materials allow students and trainees to pursue optional careers in nuclear technology.

In addition to nuclear fundamentals, which can be provided by a school, NRC licensing requirements dictate that an operator have experience in the specific plant and on the specialized equipment to be operated. The role of a two-year, post-secondary school program is to prepare nuclear QA/QC technicians who are well grounded in nuclear and power plant fundamentals. Therefore, the materials described in this Guide meet the need for the QA/QC technician position.

POWER PLANT OPERATOR TRAINEE

The nuclear reactor (plant) operator is responsible for proper routine and emergency operation of the facility. This job is the most critical in the plant from the standpoint

of responsibility and licensing requirements. Training, experience and performance under stress all figure into the ultimate selection process by which such an operator is licensed by the Nuclear Regulatory Commission (NRC) and employed by an electric utility.

San Onofre nuclear power plant near San Clemente, California.

(It has been noted that any shutdown, due to accident or operator error, of an average 1000-MWe power plant can result in a minimum revenue loss equivalent to an operator's salary over a ten-year period. Thus, an operator must combine good judgment with exceptional skill – a combination of learned capabilities best founded on adequate technical education and experience.)

RADIATION PROTECTION TECHNICIAN

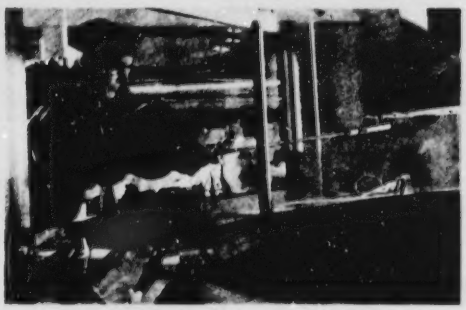
An inherent characteristic of energy is its potential for doing harm to life and property if allowed to get out of control. This potential existed with the most primitive uses of fire by man, and it exists in the most advanced applications of nuclear fission. Special care must be taken to prevent uncontrolled nuclear radiation. Skilled technicians must

Radiation protection – protection for employees and the environment.

monitor and control radiation levels. Radiation protection technicians measure the intensity and identify types of radiation and contamination.

NUCLEAR MATERIALS PROCESSING TECHNICIAN

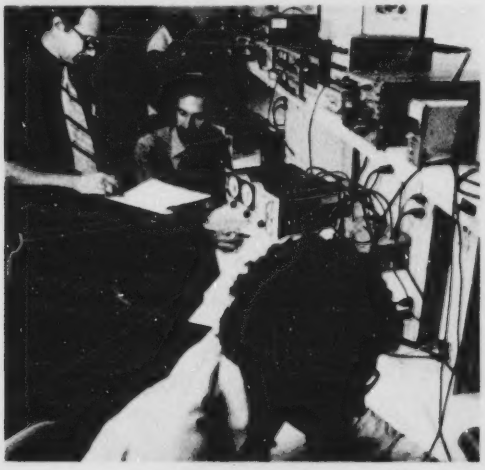
This technician performs a variety of tasks related to the milling, conversion, separation and fabrication of nuclear materials and fuels; and he may perform tasks related to fuel reprocessing, waste management, radioactive materials and materials irradiation.



Materials handling requires skill and knowledge.

NUCLEAR INSTRUMENTATION AND CONTROL SYSTEM TECHNICIAN

Instrumentation has long enjoyed its own "technology." A nuclear instrumentation technician must employ all the skills and knowledge attributable to the basic technology plus those unique to nuclear. Duties include inspection, analysis, calibration, repairs, and routine maintenance of instrumentation and control systems (including computer maintenance) throughout the plant.



Calibration, maintenance and repair of nuclear instruments require special training.

OTHER OPPORTUNITIES IN NUCLEAR TECHNOLOGY

In general, job descriptions indicated above apply to the nuclear power plant workforce – the requirements for nuclear technicians are concentrated in this industry; however, equally challenging and rewarding opportunities exist in the vast support and peripheral industries that supply equipment and materials to the utility companies. Also, nuclear research and medicine utilize technicians in large numbers. Thus, applications of the technology, already widespread, continue to expand.

Support industries, such as nuclear fuel rod fabrication, provide job opportunities.

In general, expanding technological applications indicate an expanding workforce requirement. Certainly, this generality holds true for the nuclear field.

NATIONAL WORKFORCE REQUIREMENTS

Nuclear power plants span the nation and much of the developed world. And, because the nuclear technology workforce requirements and growth applicable to this Guide appear proportional to nuclear power production, the existence and foreseeable expansion of nuclear plants may be used as a needs assessment base.

In 1970, Wayne L. Rodgers, Director of Eastern Idaho Vocational School (Idaho Falls) correctly prophesied:

> The heaviest employment of nuclear technicians is with the Federal government. However, the distribution in employment is shifting toward reactor operators, fuel processors, and reactor vendors and manufacturers.

As of early 1979, Nuclear Regulatory Commission (NRC) licenses were valid for 1482 senior re-

actor operators and 1069 operators. (In their published lists, NRC makes no distinction between power plant reactor operators and operators of research reactors.) Reactor operator projections for the period 1979 through 1987 suggest an increase from the current total of about 2500 to well over 6000. This increase suggests an annual need for at least 1200 trainees to provide an average of about 700 new licensed reactor operators to meet the needs of growth requirements and attrition. Needs analyses indicate similar workforce requirements throughout the nuclear industry.

To support these operators, at the technician level only, all the jobs described previously also must be filled.

As more and more nuclear power plants are constructed, more QA/QC technicians should be needed. By 1990 more than 200 nuclear power plants are expected to be operational in the United States, almost three times as many as in 1980.

QA/QC technicians also should find employment in other nuclear facilities and with nuclear component manufacturers. Employment as non-nuclear QA/QC technicians is also available. Potential employers include the following:

- Nuclear Electric Utilities.
- Power Plant Construction Contractors and Consultants.
- Nuclear Materials Handling and Processing Facilities.
- Manufacturers of Components for Nuclear Facilities.
- Non-Destructive Examination Firms.
- General and Specialty Contractors.
- Architectural and Engineering Firms.
- National Laboratories.

KNOWLEDGE AND SKILLS REQUIREMENTS FOR NUCLEAR QA/QC TECHNICIANS

A significant element of any needs assessment is a determination of the specific skills graduate technicians must possess to complete those tasks they might reasonably be expected to perform (sometimes these requirements are referred to as entry-level skills). These determinations must identify the minimum knowledge and skills a student should acquire prior to graduation.

The QA/QC technician must be able to perform the following tasks:

- Keep thorough and accurate records.
- Read and interpret blueprints.
- Identify the components and inspect the quality of pumps, valves, seals and piping.
- Perform instrument reading and calibration techniques.
- Determine and/or verify proper storage and handling of components such as in heated areas, inert gas atmospheres, air conditioned areas, and humidity controlled areas.
- Write complete reports, such as results of equipment inspection, radiographs, non-destructive examination reports, survey reports, construction inspection reports, acceptance test reports, etc.
- Understand and apply codes and regulations, such as the ASME Boiler and Pressure Vessel Code and ANSI 45-2 series.
- Judge the quality of various types of weld joints for a variety of material types and weld configurations.
- Perform metallurgical examinations, such as hardness, tensile strength, notch ductility.
- Understand basic metallurgical processes, such as heat treating and welding.
- Use strain gages, vibration tester, etc.
- Make accurate dimensional measurements, using micrometer, go/no-go gages, gage blocks, etc.
- Operate measuring instruments and test equipment.
- Understand and interpret criteria for passing or failing quality control tests.
- Verify control of conditions, including ambient or environmental conditions, during tests.
- Perform and verify non-destructive examination (NDE).

- Follow test procedures, and obtain/verify amount and type of data needed.
- Measure force, momentum, surface roughness, mass, temperature, pressure, hardness, etc., using appropriate equipment.
- Interpret standards on screws, bolts, and pipes.
- Assist in evaluation of customer requirements.
- Review documentation for standards conformance.
- Validate proof and qualification tests.
- Provide information on previous quality problems.
- Evaluate the quality of work performed by potential vendors.
- Review purchase orders and subcontracts for quality standards.
- Ensure that purchased materials conform to requirements.
- Recommend corrective action when material or components are below acceptable quality.
- Determine quality of manufacturing equipment, processes, testing and test equipment.
- Ensure that measuring and test equipment has been calibrated and maintained.
- Conduct follow-up examinations to ensure that corrective action is accomplished in a timely manner.
- Verify compliance of the handling, preservation, and packaging of material and equipment from receipt through shipment.
- Ensure that spares and technical supplies conform to quality requirements.
- Ensure that repairs and modifications are performed in accordance with approved standards.
- Conduct cost-reduction studies.
- Conduct audits of records and of corrective measures.

Initial preparation of nuclear quality assurance and quality control technicians is the natural province of two-year, post-secondary schools. Employers have borne much of the brunt of training effort in this field until now, but such basic educational programs are sometimes at variance with their innouse training role. Thus, assumption of a strong role by schools would be an appropriate move toward proper realignment of nuclear technical education.

Such a move should lift an unnatural burden from industry (pre-entry level training), open new opportunities for successful instructional programs to schools, open new career opportunities to students and add stability to communities in which such schools and industries are situated.

Program requirements — faculty, facilities, equipment, supplies and cost estimates — (discussed in the following section) include classroom-laboratory-office-storage floor space and a department head with appropriate technical comprehension and industrial experience. Also, such a program calls for a quality curriculum and appropriate instructional materials.

INSTRUCTIONAL PROGRAM

The curriculum outlined in this section was derived from the task inventory described in the first section.

CURRICULUM

The Nuclear Quality-Assurance/Quality-Control Technician curriculum incorporates learning objectives and supporting objectives based upon related knowledge as well as the tasks the technician is expected to perform in industry today.

Even though the curriculum design specifically relates to the training of nuclear QA/QC technicians, every course and every module invites multiple application, as demonstrated in the chart on page .

An example of the curriculum is indicated below.

	Periods/Week		
	Class	Lab	Total
First Quarter			
Introduction to Nuclear Technology	2	3	5
*Radiation Physics (Course 1)	3	3	6
Mathematics I	3	2	5
Fundamentals of Electricity and Electronics	3	3	6
Introduction to Technical Communications	2	2	4
Elective	1	0	1
	14	13	27
Second Quarter			
*Radiation Detection and Measurement (Course 11)	3	4	7
Chemistry I	3	6	9
*Radiation Protection I (Course 2)	3	3	6
Mathematics II	3	2	5
	12	15	27
Third Quarter			
Basic Mechanics	3	3	6
*Introduction to Quality Assurance/Quality Control (Course 14)	2	3	5
*Principles of Process Instrumentation (Course 3)	3	3	6
Blueprint Reading	1	3	4
*Metrology (Course 27)	1	3	4
*Metallurgy and Metals Properties (Course 15)	3	3	6
	13	18	31
Fourth Quarter			
Technical Writing	2	3	5
*Introduction to Nuclear Systems (Course 5)	3	4	7
*Mechanical Component Characteristics and Specifications (Course 16)	3	3	6
*Non-destructive Examination (NDE) Techniques (Course 26)	3	4	7
	11	14	25
Fifth Quarter			
*Welding Inspection (Course 28)	3	3	6
*Civil/Structural Inspection (Course 29)	3	3	6
*Mechanical Inspection (Course 30)	3	4	7
*Non-destructive Examination (NDE) Techniques II (Course 32)	3	4	7
	12	14	26
Sixth Quarter			
Special Projects	4	8	12
*Quality Assurance Practices (Course 31)	3	3	6
Electives	6	6	12
	13	17	30

*Technical specialty courses for which instructional modules have been developed.

COURSE DESCRIPTION

Each course in the curriculum is described to indicate both its content and its relevance to the overal program.

FIRST QUARTER

Introduction to Nuclear Technology. An introduction to the principles and applications of nuclear energy. Student is introduced to basic principles involved in nuclear radiation, nuclear sources, reactors and fuel cycles. Essential features of a nuclear power plant are discussed. Student also learns how radionuclides and radiation have application in industry and medicine. Nuclear safety will be emphasized and radiation effects evaluated. Lab sessions will include field trips, films and guest speakers. (Note: Materials for this course should be obtained from nuclear utility public relations offices.)

*Radiation Physics. An introductory course in basic concepts of nuclear radiation. Main topics covered include atomic and nuclear structure, radioactivity and interaction of radiation with matter. Student is introduced to basic radiation and measuring instruments, including Geiger-Müeller counters and personnel monitoring devices.

Mathematics I. A course in algebra, geometry and introductory trigonometry. Includes ratios, linear equations, plotting, reading and interpreting graphs and sinusoids. Math labs are problem sessions, preferably conducted by the nuclear faculty.

Fundamentals of Electricity and Electronics. A study of basic principles of direct current and alternating current, series and parallel circuit analyses utilizing Ohm's and Watt's laws, basic motors, generators and relays.

Introduction to Technical Communications. An introduction to the nature of communication skills and thinking processes with practical exercises in writing, reading, speaking, spelling and vocabulary as related to technical areas. Emphasis on writing, making reports and utilizing the use of a memoranda.

Elective.

*Technical specialty courses.

SECOND QUARTER

*Radiation Detection and Measurement. A course in principles and methods used to detect and measure radiation, with emphasis on ionization and scintillation detectors. Statistics of counting will be introduced. Properties of α, β and γ will be studied.

Chemistry I. Basic chemical principles are introduced, using modern laboratory techniques to demonstrate concepts, including atomic structure of matter, formulae, composition and bonding, the electrical nature of matter, acids, bases, oxides, salts and salt solutions.

*Radiation Protection I. An introductory course to familiarize student with the field of radiation protection, the art and science of protecting human beings from injury by radiation. Specific topics include dose and exposure measurements and units, biological effects of radiation, Federal Regulations of exposures and internal exposure evaluations.

Mathematics II. A continuation of Mathematics I; algebra includes logarithms to base 10 and base e and exponentials; geometry and trigonometry emphasizing slopes, rates of change and solutions of equations and problems with transcendental functions.

THIRD QUARTER

Basic Mechanics. An introductory course in mechanics, to teach mass, force, acceleration, velocity, momentum, energy, power and conversion of units.

*Introduction to Quality Assurance and Quality Control. An introductory course in quality assurance and quality control, including such topics as history and purpose of quality control, terms and definitions, codes and standards, publications and quality assurance/quality control procedures.

*Principles of Process Instrumentation. A course to teach principles of operation, calibration and maintenance of process instrumentation found in electrical power generating plants (includes all non-nuclear instrumentation). Specific topics include flow, temperature and pressure instrumentation.

Blueprint Reading. A basic study of industrial blueprints, process flow sheets, piping symbols and instrumentation symbols, schematics, logic diagrams and computer circuitry.

*Metrology. A study of the science of measurement and its applications. Emphasis is placed upon precision, accuracy, calibration, and dimensional measurements, using micrometers, vernier gages, depth and height gages, dial indicators, etc.

*Metallurgy and Metals Properties. An introductory study designed to acquaint student with basic metallurgical concepts and metals properties. Many basic physical properties are discussed and related to the behavior of metals and alloys. A preliminary study of metal structure is initiated. Properties of stainless steel and carbon steel are stressed. Student will be introduced to destructive examination techniques, including nick break, bend, tensile, hardness, impact, fatigue and microsectioning.

FOURTH QUARTER

Technical Writing. A study of effective ways of presenting information with emphasis on the use of logs, keeping of records and notebooks, use of graphs, drawings and sketches, and various types of reports.

*Introduction to Nuclear Systems. Course includes basic understanding of all major components of the reactor core, pressure vessel, shielding, and primary cooling water systems. Differences between PWR's and BWR's are discussed. The basic nuclear fuel cycle also is discussed.

*Mechanical Component Characteristics and Specifications. A course designed to acquaint student with mechanical components and equipment found in an electrical power generating plant or similar industrial facility.

*Non-destructive Examination (NDE) Techniques. A general introduction of non-destructive examination techniques, with emphasis placed upon radiographic testing.

FIFTH QUARTER

*Welding Inspection. The student is introduced to the methods used in welding inspection. A general introduction to welding processes is given. No previous welding knowledge or experience is required.

*Civil/Structural Inspection. The student is introduced to the methods used in civil/structural inspection. Emphasis is placed upon concrete and steel.

*Mechanical Inspection. The student is introduced to the methods used in mechanical inspection. The student should be familiar with various types of mechanical components and equipment.

*Non-destructive Examination (NDE) Techniques II. A continuation of NDE Techniques I, with emphasis placed on ultrasonic, magnetic particle, and liquid penetrant testing.

SIXTH QUARTER

Special Projects. This course is designed to allow the student to achieve a higher degree of specialization than otherwise would be possible. The student will work on a project closely related to the chosen specialty. This course should be taken in the last school quarter.

*Quality Assurance Practices. The student is introduced to various practices and procedures present in a typical quality-assurance program.

Electives.

*Technical Specialty Courses.

COURSE OPTIONS

As noted previously, almost any nuclear-related training program could utilize material from the model curriculum. Nuclear technology options for these technicians are illustrated in the chart below. Courses 1, 2, 11 and 14 are common to each of the five technology curricula. Numerous other courses are common to two or more of the curricula.

At least two program options or specialties are recommended at schools for several reasons. 1) Quality-assurance/quality-control job requirements exclude some students for reasons other than educational non-achievement; e.g., personality traits. 2) A temporary shift in workforce requirements may favor an option. 3) Student interest may change after the first year of co-op experience.

COURSE NO.	TECHNICAL COURSE TITLE	NUMBER OF MODULES	NUCLEAR REACTOR (PLANT) OPERATOR TRAINEE	RADIATION PROTECTION TECHNICIAN	NUCLEAR MATERIALS PROCESSING TECHNICIAN	NUCLEAR QUALITY – ASSURANCE/QUALITY – CONTROL TECHNICIAN	NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN
1	Radiation Physics	6	1	1	1	1	1
2	Radiation Protection I	6	2	2	2	2	2
3	Principles of Process Instrumentation	8	3		3	3	3
4	Heat Transfer and Fluid Flow	8*	3				4
5	Introduction to Nuclear Systems	6	4	3		4	4
6	Instrumentation and Control of Reactors and Plant Systems	6	5				5
7	Reactor Operations	7	6				
8	Reactor Safety	5	5				
9	Reactor Auxiliary Systems	4	6				
10	Power Plant Systems	9	5				
11	Radiation Detection and Measurement	8	2	2	2	2	2
12	Reactor Physics	6	4				4
13	Power Plant Chemistry	7	6	4			
14	Introduction to Quality-Assurance/ Quality-Control	9	3	3	3	3	3
15	Metallurgy and Metals Properties	8	3		4	3	
16	Mechanical Component Characteristics and Specifications	8	4			4	
17	Radiation Protection II	5		4	4		
18	Radiological Emergencies	7		4			
19	Radiation Shielding	6		5			
20	Radiation Monitoring Techniques	7		5	5		
21	Radioactive Materials Disposal and Management	7		5			
22	Advanced Radionuclide Analysis	7		6			
23	Nuclear Chemical Processes	7			5		
24	Nuclear Systems and Safety	8**			6		
25	Radioactive Material Handling Techniques	8***			6		
26	Nondestructive Examination (NDE) Techniques I	7				4	
27	Metrology	8			3	3	
28	Welding Inspection	11				5	
29	Civil/Structural Inspection	8				5	
30	Mechanical Inspection	8				5	
31	Quality Assurance Practices	8				6	
32	Nondestructive Examination (NDE) Techniques II	6				5	
33	Control Systems I	6					5
34	Control Systems II	7					6
35	Power Plant Electrical Systems and Components	7					6

*Course 4 modified for I&C only

**Module 24.1 is 12.1
24.2 is 12.2
24.3 is 12.3

***Module 25.6 is 21.1
25.7 is 21.6
25.8 is 21.4

NOTE: Numbers in columns denote suggested quarter for use of the courses.

INSTRUCTIONAL MATERIALS

The basis of a sound instructional program is well prepared materials. If scrupulously reviewed by educators and employers, revised and tested, such materials best serve the instructional program, the students and the ultimate employers. The best materials also meet stringent content requirements for flexibility, relevance, currency and validity.

MATERIAL CONTENT AND FORMAT

As noted earlier, nuclear technology encompasses a variety of technical job opportunities with equally great variations in knowledge-and-skills requirements. A curriculum that offers a two-year QA/QC technician program with options for several nuclear-related jobs must be flexible enough to be adapted to specific employer needs on a local basis. Modular materials allow pin-point selection of appropriate instructional units; for example, the instrumentation technician, whose major involvement is with instruments, with only an incidental involvement in nuclear, should be allowed to select those instructional units applicable to that limited involvement. The flexibility of brief, single-subject, self-contained modules allows a curriculum — whether a seminar, short course, course option or full course — to be custom designed to meet specific needs.

The curriculum material is passed through a variety of critical reviews to ensure its relevancy. Local instructional needs, determined by a local or regional needs assessment and task inventory, make selection of material relevant to local, current needs possible.

Historically, technical instructional materials have evolved slowly. Too often, materials became available at about the same time they became obsolete. To eliminate this problem, the materials described in this Guide are being offered within months — sometimes, weeks — following their initial preparation by authors and reviewers involved in the state-of-the-art technology. Further, through continuing efforts of the National Steering Committee for Nuclear Technician Training, technological advances as well as national employment opportunities are reviewed and relevant data is passed on to institutions and organizations using the materials.

The materials are updated as necessary to ensure currency. The most effective manner of ensuring currency, however, is for users of the material to utilize their local industrial advisory committee (IAC) to keep the local program up to the minute on technological changes, variations and workforce requirement fluctuations. (Note: An IAC is described in the following section in detail.)

From the educator's standpoint, educational materials must assume a valid educational format. In this case, the materials are presented in a strictly cognitive form; that is, objectives are stated in "action" terms (perform, calibrate, draw, list, measure), and each module as well as its procedures emphasizes manipulative skills, founded on valid, relevant theory and practice.

Thus, each module, as well as the entire curriculum for nuclear quality assurance/quality control technicians, consists of valid, current, relevant and flexible materials.

MODULE ELEMENTS

Instructional modules developed specifically for this nuclear quality-assurance/quality-control technician curriculum contain these basic elements:

Introduction: Identifies topic (and often includes rationale for studying the material).

Module Prerequisites: Identifies knowledge and skills students should possess before studying the module.

Objectives: Clearly identifies what the student is expected to know and do upon completion of the module. Objectives are stated in terms of action-oriented behaviors, including such terms as "operate," "measure," "calculate," "identify," and define," instead of words with many interpretations, such as "know," "understand," "learn" and "appreciate."

Subject Matter: Presents background, theory and techniques supporting the objectives. (Subject matter is written with the technical student in mind.)

Exercises: Provides practical problems to which student can apply new knowledge from module study.

Materials: Identifies equipment required to complete laboratory procedures.

Procedures: Presents experiments or "hands-on" activities, including step-by-step instructions. (Experiments are designed to reinforce student learning.)

Data Tables: Included in most first-year or basic-course modules, the data tables help students learn how to collect and organize data.

Reference Materials: Presents suggestions for supplementary reading.

Test: Measures each student's achievement against objectives stated at the beginning of the module.

Modules average approximately 30 typewritten pages, including illustrations. (Illustrations normally are line drawings that are easily understood and can be reproduced on copy machines for overhead projection.) New modules can be added easily, or existing ones modified, for self-paced instruction or short courses.

A description of the courses and their modules appears in Appendix B. Course and module titles for materials developed for the other four curricula are indicated also.

An exhaustive index for each course is scheduled for completion in August, 1980. In addition to this index in the back of each course, a general index to all 35 courses will be available in a separate volume. These indexes will be excellent aids (1) for planners who wish to determine the exact content of each module or course, (2) for students and instructors who must locate materials in the various courses, and (3) for researchers who use the courses as library or plant references.

INDUSTRY TRAINING PROGRAMS

Planning a training program within an industry differs from institutional planning — employer needs dictate program content.

The following Table presents a typical QA/QC training program within the nuclear industry. The shorter workshop program there outlined is a typical refresher and introductory project for management personnel.

TYPICAL IN-HOUSE TRAINING PROGRAM FOR
QUALITY ASSURANCE/QUALITY CONTROL TECHNICIANS

Course	Course Number of Parallel Courses Described in this Guide
Non-destructive Examination	32
Welding	15, 28
Codes and Standards	26
Magnetic Particle/Liquid Penetrant Inspection Methods	14, 28
Radiographic Inspection	14, 26
Radiographic Interpretation	26
Visual Inspection (including Drawing Interpretation and Metrology)	26, 27, 29
Equipment (including Lab-testing Techniques)	5, 6, 27, 30
Documentation and Record Keeping	14, 31
Radiological Safety	2, 11, 14
Health Physics	1, 2
Audits for the Nuclear Power Industry	31
Managing Cost of Quality	14, 31

TYPICAL QUALITY ASSURANCE WORKSHOP

Subject	Classroom Hours	Course Numbers of Parallel Courses Described in this Guide
Introduction to Quality Assurance Requirements for Operating Nuclear Power Plants	4	14, 26, 32
Developing an Operating Quality Assurance Program	4	14, 26, 32
Management Functions in Operating Quality Assurance	4	14, 26, 32
Implementing an Operating Quality Assurance Program	8	14, 26, 32
Conducting Operating Quality Assurance Audits	4	14, 31

Modular curriculum materials adapt readily to such industrial training programs. Also, they fill the need for less comprehensive short courses and seminars presented by industry or technical associations and intended for updating or upgrading employees.

Module procedures are directed primarily toward students at two-year institutions who have no experience or familiarity with specialized equipment. When an employer uses the instructional modules for employee retraining, the procedures or lab activities should be selectively omitted or replaced.

COOPERATIVE EDUCATION

This technology is adaptable to a cooperative arrangement: a plan which offers important advantages to students, to the school, and to employers of technicians. A cooperative education program provides an opportunity for a student to learn through coordinated study and employment experience. Students alternate periods of attendance at the institution where they study their technical program with periods of supervised employment in business or industry, which provides both training and work experience. The employment constitutes an essential element in their education. The students' employment should be closely related to the field of study in which they are engaged.

When students test their knowledge of theory in a work situation, study becomes more meaningful. Co-op students learn not only the essentials of the technology but also the importance of reliability, cooperation, and judgment as an employed worker in a chosen occupational field.

Co-op students' career choices are stimulated and strengthened by work experiences. A satisfactory work experience provided in a co-op program assists in stimulating the students' interest and effectiveness in the institutional phase of the program, making it more meaningful. The experience in a co-op program also assists students in knowing if they have made the proper occupational choice prior to completing their educational program and entering employment.

A class of students in cooperative technical programs usually spends the first semester or the first two quarters in school; then time is divided so that half the students have a semester or quarter of employment experience while the other half continues to study. During the next semester or quarter, the half who have worked return to their formal studies at school while the other half are employed. They usually alternate again so that each student has two semesters or at least two quarters of work experience in the program. The students' technical program is lengthened beyond the curriculum outlined in this Guide by the amount of time equal to the total length of the employment experience.

Specific employment is obtained, as circumstances permit, by the educational institution with the cooperation of the student. The institution regards the work-experience program as an integral part of the technician program as a whole. It is not regarded primarily as an opportunity for earning, although each student while working is paid at the prevailing wage scale for the job performed. Work reports by both the student and the employer are submitted to the school work program coordinator.

The cooperative work-experience program is an opportunity for the students to gain directly related experience, which makes them more valuable as employees. As a result of the work-experience in particular establishments, many students are offered permanent positions upon completion of schooling. Cooperating establishments agree, however, not to make offers of employment that become effective before a trainee completes the program.

Cooperative programs provide opportunities for the educational institution to maintain close contact with employers in their various programs. This contact becomes a two-way channel of communication, which helps the educational institution keep its knowledge of specific employer needs in each technical field up to date. At the same time, it keeps employers acquainted with and involved in the institution's program(s).

PLANNING A PROGRAM

Planning should begin with establishment of an advisory committee and a determination of needs, followed by an evaluation of local potential for meeting such needs.* Considerations include:

Faculty.
Student Selection and Services.
Facilities.
Equipment.
Library.
Cost.

The extent and implications of each of these considerations are explored following the discussion of needs.

NEEDS DETERMINATION AND EVALUATION

By using accumulated data and a local industrial advisory committee, a program planner may develop a preliminary local or regional needs determination. The needs determination should consist of a survey documenting: number of existing employers; number of job vacancies; number of expected vacancies in 2, 5, and 10 years, other titles given this same job; job entry specifications; type of need — whether for new employees or retraining of existing employees; and anticipated salary range. A typical survey document is shown in Appendix C.

Once a program-sustaining need is determined, the planning considerations listed earlier should be given detailed attention.

ADVISORY COMMITTEE

The success of this program depends, to a great extent, on the formal and informal support of an advisory committee. This committee should be appointed by the chief administrative officer of the institution and should be comprised of local (or regional) employers of reactor operators and technicians. These members serve without compensation. The committee normally consists of about ten members who should serve from two to three years with staggered terms.

The local advisory committee should assist in studies to determine and define the following: the need for the technical assistant program; the knowledge and skills technicians will require; employment opportunities; available student enrollment; curriculum content; faculty qualifications; laboratory facilities and equipment; resources both with and outside the institution; and cost and financing of the program. If the survey indicates that a program should be initiated, and will be supported, the committee's help in planning and implementing it is invaluable.

The survey should take a form other than an informal question or two to associates of the committee members. It is suggested that a needs assessment instrument (similar to the one shown in Appendix C) be distributed to the employers in the region around the training institution. The form does not have to be elaborate and could be derived from performance objectives stated in this Guide. A checklist of performance objectives, filled out by various employers, gives the school a rather clear outline of the knowledge and skills needed by a trainee to be hired in the community.

When the survey instruments are returned to the school, they should be compiled for use in a task inventory for the occupation. A review of this task inventory by the advisory committee is essential at this point. Resurveying at periodic intervals and changing course content accordingly

*In addition to the "ideas" presented in this Guide to facilitate curriculum planning, members of the project staff and the National Steering Committee are available for consultation and assistance in planning (and implementing) a nuclear program.

keeps the training program up-to-date and ensures that trainees have a better chance for employment. In today's world of specialized skills and employment, the old concept of curriculum by guess or by past procedure is a disservice to the student and to the training institution.

The advisory committee should understand that the program is not intended to make individual students proficient in all duties they might be asked to perform at all types of nuclear reactors. Proficiency in highly specialized work comes from experience and further education, or both. It is impossible to accurately predict the rate of change within various work situations. Employers should expect to provide reasonable on-the-job orientation to acquaint the new employee with operational procedures of the facility.

Upon implementation, the committee provides continuing liaison between the institution and employers. Frequently, the committee helps administrators obtain local funds and state and Federal support for the program. The committee also aids in placement of graduates of the program and in evaluating the performance of the graduates on the job. Such evaluations often indicate minor modifications that more closely align the program with employment requirements and opportunities.

The committee should meet as regularly as needed and should keep formal minutes of its proceedings (which could become, in compilation, an annual report of the proceedings). For further elaboration on the role and responsibilities of the advisory committee in technical education programs, refer to Riendeau's Advisory Committees for Occupational Education: A Guide to Organization and Operation.*

This Guide, designed primarily for planning and development of full-time programs in post high school institutions, can be used by the administrator of the institution and an advisory committee as a starting point for development of their own program. It can and should be modified where necessary and adapted to meet local needs and institutional criteria.

FACULTY

The effectiveness of the program and the curriculum depends largely upon the competence and enthusiasm of the teaching staff. With a qualified and interested faculty, a needed educational program may flourish. Qualified faculty members may exist at the institution or within the industry or organization planning the program, or it may be necessary to recruit a faculty from outside sources. In any event, faculty consideration includes these recommended items:

Numerical Requirements. The number of faculty members needed is based on the duties assigned each member, number of students in the program (first and/or second year) and number of courses scheduled for instruction. The typical teaching load is 18 – 24 class/lab hours per week with the department head assigned not more than 12 hours, allowing time for administrative duties. In the first year, the department head would be responsible for instruction of 24 students. A full-

*Albert J. Riendeau. Advisory Committees for Occupational Education: A Guide to Organization and Operation. New York: McGraw-Hill, 1977.

time instructor would be added in the second year. (See Appendix G for sample costing calculations.)

Competency. The department head should have a strong academic grounding in nuclear technology (BS degree in nuclear engineering or science, or equivalent) and suitable experience in industry (e.g., 2 years or more as a QA/QC technician or supervisor). An instructor must have sufficient grounding in the technology (such as might be received from a well-organized tech school course), work experience or service in the nuclear navy.

Availability. Qualified personnel must be available within a suitable time frame. (Assistance in identifying faculty requirements and in locating qualified personnel may be obtained from the local industrial advisory committee.)

Affordability. The salary structure is a prime consideration. Instructors with experience in the nuclear industry command salaries competitive with industry. An institution must be prepared to pay more for nuclear technology instructors than for welding or mechanic instructors – perhaps even more than some of the dean or campus managers.

Technical programs are designed to produce supportive employees who increase the effectiveness of the total workforce. This principle should be applied to increase the effectiveness of the teaching staff.

Adequate time should be set aside to allow new staff personnel to review the curriculum materials, to visit – if possible – a successful program and its faculty, and to engage in a brief teacher training or familiarization program. The latter program should be designed to ensure that the teacher has an adequate overview of the curriculum materials and a general appreciation of the modular concept. Also, if possible, the teacher should be afforded an opportunity to dialogue with developers of the material, thereby resolving any variances between intended meaning and interpretation.

Staff assistants may be used in stock control to set out the proper equipment for laboratory classes, to keep equipment operating properly, to assist in the development of teaching materials, supervise laboratories, and do a limited amount of routine paper grading and project checking.

By adjusting the size of the supportive staff to the demands of enrollment, a school may partially solve the problem of staffing instructors when it is necessary to teach a number of different courses in one term. Supportive staff members may be recruited from the student body or from graduates of the program.

New approaches to the organization of faculty should be considered. Team teaching is one possible approach. In this sense, team teaching is the organization of a technical staff into a coordinated teaching unit. Teaching assignments are made on the basis of the individual member's special training and talents. Team planning allows for concurrent courses to be closely coordinated by team members to best utilize the student's time while the student is moved smoothly to progressively higher levels.

A weekly departmental staff meeting to encourage and sustain team teaching efforts is recommended. At these meetings, team members can assess and evaluate progress and plan on the basis of this evaluation and on current developments. This is especially important when a new course or a new technique is involved.

In addition to coordinating concurrent courses, staff meetings provide for free exchange of ideas on teaching techniques discovered to be useful and on recently developed laboratory projects which seem to be particularly successful.

To help keep a staff effective, an in-

stitution should encourage all staff members to up-date their knowledge of current industrial practice. Their knowledge of teaching techniques and innovations in education must continue to grow and expand. Membership in professional and educational associations should be encouraged, together with active participation in professional association work at local, state, regional and national levels. Through such organizations, faculty can keep up with new literature in the field and maintain closer liaison with employers.

Close contact with employers will also ensure success of the program through the following areas:

Employment of graduates.
Opportunities for cooperative education.
Assistance in organizing and presenting short courses and conferences.
Donations of equipment and scholarships.
A viable industrial advisory committee.

STUDENT SELECTION AND SERVICES

Preparing functionally competent nuclear quality assurance/quality control technicians makes three major demands upon the training program: 1) the training should equip graduates to take an entry job in which they will be productive; 2) it should enable graduates to advance to positions of increasing responsibility after a reasonable amount of experience; and 3) it should provide a comprehensive foundation to support further study.

Students entering the program should have certain capabilities, including comprehension and knowledge of underlying subject areas and related skills and adequate study habits and language competencies.

The program described in this Guide is designed for the typical average student (high school graduate or equivalent with one year of math and one basic science course); however, ability levels of those who enter the program generally vary greatly. Many students, whose intelligence and interest make them capable of mastering the curriculum required in the program, have under-developed scholastic skills. If applicants for admission to the program do not have the necessary scholastic background and skills, they should be given an opportunity to enter an organized program for the development of prerequisite skills before entering the technical program. This would ensure them a good probability of successfully completing the technical program. The institution should provide developmental programs to give students this opportunity.

Personal interviews with prospective students for the purpose of effective guidance and counseling are essential. Students should be given interest and aptitude tests by the guidance and counseling departments of the institution to assist them in selecting educational and occupational objectives consistent with their interests and abilities. This will assist them in determining their career objectives and selecting the programs appropriate to their interests.

Students should be given a thorough orientation program upon entry to the institution. This program should include an orientation to the facilities available on the campus, including the student lounge, dining areas, bookstores and recreational facilities. In particular, they should be given a comprehensive tour of the library to familiarize them with its various facilities and procedures and rules governing its use.

Students should be provided information regarding student membership in technical and professional organizations, locally, statewide, and nationally, and encouraged to join such organizations. Membership in professional organizations provides students with an opportunity to receive excellent material on a regular basis at a substantial reduction in cost, to associate with other people in the field at meetings and to develop a habit of

regularly reading journal articles to keep their technical knowledge in the field current.

Graduates of the program should be aided in every way in finding suitable employment. Placement of graduates is an important and multifaceted responsibility involving the placement department, the department head and instructors, and, either directly or indirectly, the advisory committee. However, the primary placement responsibility in new and changing technologies should rest upon the department faculty. They should send out announcements of upcoming graduates to the respondents of the needs survey and to committee members. Outstanding and successfully placed graduates and their employers are the most effective advertisers of the program.

The institution should conduct periodic follow-up studies of graduates to improve curriculum and teaching techniques, evaluate training effectiveness, maintain good employer-employee relationships, and provide a continuing evaluation of the total program.

FACILITIES

Industrial training programs vary widely according to need — from classrooms in a plant to sophisticated, specialized training centers; therefore, this discussion applies more specifically to institutional planners whose needs may be standardized to some extent.

For institutions, facility requirements of approximately 2000 square feet include the usual classroom(s), laboratory(ies), storage area(s), and staff office(s). Whenever possible, these areas should be combined in a single building for efficiency, economics and safety.

The following discussion assumes a class size of twenty-four students with two lab sections for each class. Thus, the classroom illustrated accommodates twenty-four to thirty students comfortably. The storage space included is adequate for audio-visual equipment and other materials normally required for classroom instruction.

A typical laboratory layout (page 24) for implementation of the complete curriculum would include all the elements shown; however, options offered as adjuncts to existing programs may adapt nuclear equipment to electronics or physics laboratories.

Two laboratories should be considered, 1) a general nuclear laboratory with radiation counting capabilities and 2) a sample preparation laboratory; it is necessary to keep counting instruments free from contamination by liquid samples.

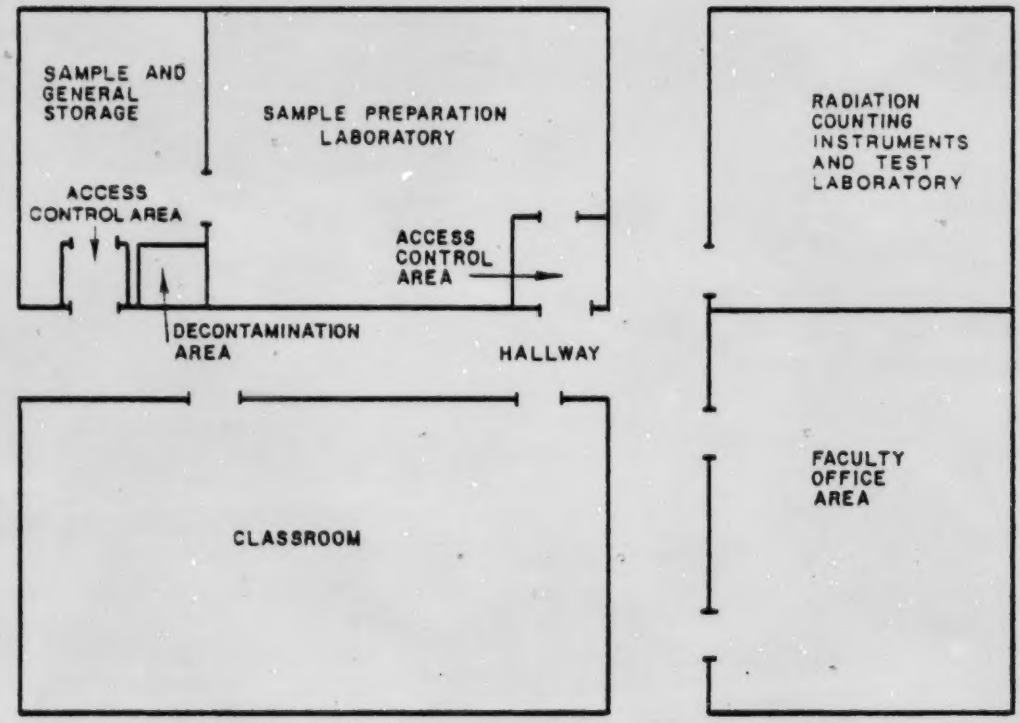
General laboratory stations should provide ample table area for radiation counting equipment, QA/Qc test equipment, and work space for students' notebooks and charts.

Sample preparation laboratory stations should be designed for handling and storing radionuclides and small radioactive sources in a workbench-type layout. Counter tops and sinks (with hot and cold water taps) should be of stainless steel for easy decontamination and cleaning. Storage drawers should be lead-lined. Key-locks should be installed to minimize unauthorized access.

A storage area adjacent to the sample preparation laboratory should include an accountability area for the storage of radioactive materials and contaminants. (Note: A system of accountability provides students with realistic, on-the-job type procedures.) Also, in this area, there should be a workbench and central tool storage.

Staff office space should differentiate between department head and instructor(s), and should place one person in each office to allow for personalized counseling.

Though new facilities may normally be acquired through established appropriation channels, some schools qualify for various special State and Federal grants. These should be explored



SUGGESTED FACILITIES FLOOR PLAN

by each school's grants department or personnel.

EQUIPMENT

Proper training of technicians for industry entails hands-on experience with industrial-type equipment, insofar as is practical. All unique items of equipment necessary for a viable program in nuclear QA/QC technician training are listed in Appendix E. This list incorporates specific items called out in each module and inlcudes special nuclear laboratory storage and handling equipment.

Each item of equipment is accompanied by a recommended quantity, based on requirements of one class of twenty-four students divided into two laboratory sections of twelve students each. Cost approximations, based on 1979 vendor catalog prices, follow each listing.

The equipment list (Appendix E) includes unique items identified by authors of the curriculum materials as necessary or desired equipment for carrying out procedures included in the modules. (Note: Equipment should be equivalent to that used in industry whenever possible.) Ordering information is included with the equipment list.

Not included in the list are the various teaching aids such as visual and audio aids.

Equipment in a sophisticated simulator control room.

Equipment teaching aids can be designed and built economically. Usually, access to a research reactor (for institutional training) or a working reactor (for industrial training) can be arranged to permit familiarity with such equipment and with the QA/QC procedures at these localities. A list of university research reactors is found in Appendix D. Also, used equipment and materials can provide excellent teaching aids. In industry-sponsored training programs, such equipment may be obtained from stock; institutions may need to look to industry – especially their industrial advisory committees – for contributions of used equipment.

LIBRARY

In each module, a list of reference materials is included. For the convenience of each institutional or industrial program developed, a suggested list of references and periodicals is presented in Appendix F.

Dynamic developments, causing rapid changes in technological science and practice, make it imperative that a student learn to use a library. Instruction for technology students should include assignments that require them to use the library so that they may form the habit of using the library as a tool in learning. This knowledge helps students develop professional attitudes and further teaches them to depend on libraries to keep abreast of new developments.

Reference materials and related media materials for teaching new technology should be reviewed continuously and revised or replaced, keeping in mind 1) the rapid development of new knowledge, techniques and procedures in the field, 2) the results of research in methodology of teaching in the field of nuclear technology, and 3) the dynamics of change within the structure and philosophy of nuclear industry. It is mandatory that instructors constantly seek and review new references and related media materials as they become available and adopt those that are an improvement over those suggested in this Guide (Appendix F), or those currently in use.

Instructors of all courses should inform their students that library use is an important part of the program. Planned assignments that require the use of a library to research additional facts and new techniques on pertinent subjects enable students to understand the resources available and their relation to technology. Open-book examinations that require use of a library provide excellent, objective experiences. Under the incentive of such examination and the pressure of time, students obtain clear understandings of their own competencies in library use.

The growth and success of a graduate technician depend largely on an ability to keep up with changes in the field.

Library content may be classified as basic encyclopedic and reference index material, reference books pertinent to nuclear technology, relevant periodicals and journals, and audio-visual aids.

Therefore, a central library, under the direction of a professional librarian, is important to the success of a technology program. Most instructors have private libraries in their offices from which they may select books of special interest to discuss in their personal conferences with students, thereby stimulating interest in related literature; however, a central library ensures acquisition and cataloging according to accepted library practices and provides systematic card files, which facilitate the location of reference materials. It also provides a controlled and orderly system for lending books to students, typical of a system they might encounter as employed technicians. Provisions for lending materials for out-of-library use should be systematic and efficient. Suitable study space should be provided students for use of references.

A limited library incorporating books referenced in the curriculum material, supplemented by appropriate specifications (e.g., 10CFR50, ASME Boiler and Pressure Vessel Code, etc.) and relevant trade journals, should be maintained in the instructional area.

COST

The information given in Appendix E affords curriculum planners adequate data for estimating equipment costs based on 1979 prices; however, once a tentative equipment list is developed, planners are urged to contact appropriate distributors (from their own associations or from the vendor list provided in Appendix E) and obtain definite price quotes.

Equipment is only one cost that should be predetermined. Facility cost includes the classroom, laboratories, offices and associated areas. It also includes furnishings, utilities, and maintenance. In most schools and industrial facilities, these items are determined on a pro-rata basis.

The cost of supplies – used in the offices as well as in the classroom and laboratories, including handouts, preprinted tests and visual aids – should be estimated as accurately as possible.

Faculty and staff costs are a significant item. The costs of field trips and faculty travel and participation in industrial advisory committee meetings, technical associations and their activities, and special seminars should be anticipated.

Making determinations of program costs becomes meaningful when decisions must be made as to 1) whether or not the program is affordable, 2) whether or not the program will be cost effective and 3) whether or not to implement the program.

To provide the program developer with a rationale for developing cost data, sample calculations are presented in Appendix G. Sample Calculation No. 1 assumes a full class – ongoing program – having department head and a full-time instructor. Calculation No. 2 assumes a typical first-year start-up program; one instructor who also acts as the department head and a minimum number of students. These calculations must not be accepted as accurately reflecting a given situation, but only as guidelines from which a program planner may extract appropriate techniques. Note that all cost estimates (including faculty) attempt to reflect both appropriation and budgetary items (for schools).

The final calculation in Appendix G applies to industry only.

PROGRAM IMPLEMENTATION AND EVALUATION

The level of effort involved in implementing a new program of instruction may vary from one setting to another, but the essential elements remain fairly constant.

IMPLEMENTATION

Implementation includes:

- Identifying needs.
- Determining curriculum requirements.
- Preparing and presenting program proposal, obtaining approval.
- Selecting and preparing staff.
- Acquiring facilities and equipment.
- Enlisting students.

LOCAL/REGIONAL NEEDS ASSESSMENT/ANALYSIS

Determination of needs consists of three steps:

Identification of employers:
(both present and potential).

Identification of jobs:
Task inventory.
Entry level requirements.
Employment projections.

Analysis of needs:
Benefits versus expenditures.

A listing of employers should be available to interested schools. Local identification of such employers can be achieved readily with the counsel of a well chosen industrial advisory committee, many of whom will be employers (or representatives of employing organizations) of nuclear operators and technicians.

With the assistance of the committee and local employers, the several aspects of job identification can be successfully completed in a relatively brief period of time. Usually, this step can be carried out by mail, utilizing properly prepared survey instruments, examples of which are presented in Appendix C.

Any new program should be self-justifying. The benefits should justify the cost. Factors entering into this analysis include:

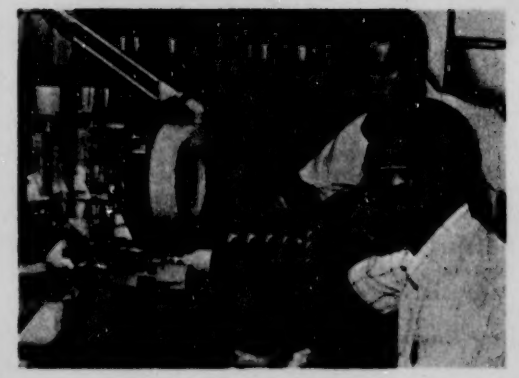
- Quantity of job opportunities.
- Quality of job opportunities.
- Projected job opportunities.
- Capability of institutions to offer program:
  - Budget.
  - Facilities.
  - Faculty.
  - Administrative fervor.
    (Without an administrative commitment, no program is apt to evolve, even though all other elements are present.)

The industrial advisory committee's expertise should be utilized in this analysis of needs. Each member should be given an opportunity to review and evaluate the cumulative results of the needs survey and the school representative's assessment of the institution's capabilities. They may be able to suggest or propose ways of overcoming certain weaknesses or shortcomings.

CURRICULUM REQUIREMENTS DETERMINATION

Because curricula must be responsive (in technical education) to the real needs of technological industry, any determination of curriculum requirements must come after a realistic assessment and analysis of industrial workforce needs. The modular curriculum suggested in this Guide for training nuclear operators and technicians can be adopted wholly or in part to meet the real needs of industry. The materials to be used should be selected with care and, preferably, with the consultation of committee members to ensure compatibility with industrial needs.

Personnel, familiar with the materials, content and sequencing and experienced in the matching of the curriculum to needs, should be utilized in developing the program. Members of the industrial advisory committee, with knowledge of workforce training needs, should



Technical education must meet industry needs.

assist in the reviewing and selecting process.

Once program implementation reaches this development point, a formal proposal – in most institutions – must be prepared and presented to appropriate administrators, boards and agencies.

PROGRAM PROPOSAL PREPARATION

Three criteria should be satisfied in presenting a successful proposal for a new technical education program.

Need (for program). This criteria should have been established by the needs assessment and analysis. All data, both supportive and detractive, should be included along with letters or directly quoted comments and opinions of industrial advisory committee members.

Capability (of institution to provide program). This criteria includes: 1) fair and comprehensive evaluation of a school's interest in the program (top executives and/or administrative support and faculty enthusiasm), 2) its budgetary potential (requires a good estimate of program's cost and enrollment potential), and 3) its available facilities.

Cost effectiveness. There are two approaches to this determination: 1) immediate effectiveness – whenever possible, a program should be self-sustaining. Thus, it is important to establish program cost versus direct economic return. All the inputs that go into making this determination, including a realistic projection of enrollment in the program, should be incorporated into this proposal; 2) long-term effectiveness – total effect of the program on school resources should be weighed against benefits to society. In many instances, these determinants must be stated in intangible terms. Even so, they should be presented fairly and as accurately as possible.

PROPOSAL FORMAT

The format of the proposal varies extensively from school to school; however, as a general rule any proposal should be as straightforward, concise and simply stated as its preparer can make it. The following elements are meant only to imply a possible outline.

Preface. (What the document is; who prepared it; for whom was it prepared?) No more than one (1) page.

The Need. Reflecting all items discussed earlier.

The Curriculum.

The Plan. Organizational approach; facilities utilization; human and financial resources.

The Cost.

The Benefits.

The Recommendations. Based on reasonably drawn conclusions.

Letters/documents of support.

Evaluation of existing compatible programs.

Once a program has received formal approval, instructional preparation becomes an immediate consideration.

EVALUATION

Human endeavor is subject to continual evaluation, generally informal, but evaluation nonetheless. It is this ongoing monitor-review activity that guides any individual or corporate activity to ultimate success — success that can only be assessed in retrospect. An educational program — human endeavor of a corporate nature — should be evaluated progressively (as well as on the basis of its end product) to ensure its constancy toward the development of a successful end product.

CURRICULUM ACCEPTANCE

While a major evaluation factor is adequate enrollment, other criteria provide significant, if not major, evaluation tools:

- Drawing power and holding power of program. Does program attract and hold qualified students in a manner comparable with similar technical programs?
- Student enthusiasm and morale. Is there an observable esprit de corps within the classes or groups of students enrolled in the program?

Enrollment figures (compared with similar technical programs or with enrollment goals or limitations) answer the first question. The second may require a more comprehensive evaluation. For example, student response to a program may be evaluated subjectively by adjudging such factors as:

- Interest/disinterest in classroom activities, laboratory procedures and homework or outside study (based on attentiveness and actions).
- Enthusiasm/indifference as related to the total program (based on attendance).
- Test scores on materials that judge student's progress in assimilating skills and knowledge essential for technical employment.

More commonly, however, evaluation tools are employed to reflect the students' responses more directly. This objective evaluation procedure (from the faculty's standpoint), which employs one or more questionnaires, seeks responses in the following areas:

- Teacher effectiveness (including lab instructors).
- Materials applicability (including understandability and program content relevance).
- Facilities and equipment adequacy.
- Student self-evaluation (including attitude, progress, and continued interest).

GRADUATE PERFORMANCE

The ultimate evaluation of a technical education program stems from the success of its graduates:

- Do their skills and knowledge meet entry-level requirements?
- Are they successful in the job market?
- Does their on-the-job performance satisfy employer expectations?
- Are they promotable?

These questions may be asked of both the graduates and their employers. (Placement records may be more indicative of a hungry job market than a successful training program; therefore, evaluation should go beyond this initial transition from student to employee.)

Graduated students, along with their employers, should also be asked to reflect upon or review the training program periodically. This means of relating program content to occupational needs should prove especially valuable in incorporating new or updating technological developments into the program.

APPENDICES

APPENDIX A

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APPENDIX B

TECHNICAL SPECIALTY COURSES AND MODULE TITLES AND DESCRIPTIONS

COURSE 1, RADIATION PHYSICS.

Module 1-1, "Introduction to Radiation Laboratory Safety."

This module examines basic radiation safety terms including: radioactivity, radiation, agreement state, monitoring radioactive waste and decontamination. Guidelines are also given which provide a method for developing specific laboratory rules relating to radiation safety.

Module 1-2, "Basic Radiation Detection and Measuring Equipment."

Included in this module is a description and discussion of the function of (a) ionization, (b) film badge, (c) dosimeter, (d) scaler, (e) ratemeter, and (f) count-rate.

Module 1-3, "Atomic Structure and Radioactivity."

This module includes basic principles of atomic structure, definition of elements and atoms, and a description of the Geiger-MUeller plateau. Each topic is illustrated with labeled diagrams.

Module 1-4, "Radioactive Decay and Half-Life."

Radioactive decay and half-life are described through the definition of (a) radioactive decay, (b) stability, (c) nuclear force, (d) electrostatic force, (e) half-life, (f) decay constant, (g) activity, (h) specific activity, (i) Avogadro's number, (j) curie, (k) nucleon, (l) gram-atomic weight, and (m) atomic weight.

Module 1-5, "Radioactive Decay Processes and Schemes."

Several aspects of particulate radiation are described including particle speed, mass in AMU, electrical charge and penetrability. Sample decay equations and decay schemes for given decay processes are illustrated. Instructions are also given for reading and interpreting the Chart of Nuclides.

Module 1-6, "Basic Properties of Gamma Radiation."

This module includes a basic description of gamma radiation and its properties.

COURSE 2, RADIATION PROTECTION I.

Module 2-1, "Radiation Exposure and Absorbed Dose Values."

This material involves a study of radiation exposure and absorbed dose values by defining the limits of usage for the units of radiation dosage, teaching rapid conversion from all systems of units into rem and explaining why quality factor is different for different types of radiation.

Module 2-2, "Biological Effects of Radiation."

The biological effects of radiation including: mechanisms by which radiation damages living body cells, typical radiation syndrome, differentiation between internal and external radiation exposures are presented. Also included is a discussion and evaluation of the hazards of biological injury to the general population versus that to the radiation worker and an explanation of the benefit versus risk concept in the use of radiation.

Module 2-3, "Radiation Protection Standards."

Initially this module examines the radiation protection standards associated with dose level exposures for accumulated whole body, extremities and skin. The correct completion of all application and report forms required by State and local standards pertinent to radiation protection and establishment and maintenance of record systems that facilitate compliance with the regulations are also included.

Module 2-4, "Internal Dose Calculations."

Various methods of internal dose calculation are discussed including: MPC, body burden, standard man, bioassay, ICRP, critical organ, handbook 69, effective half-life, empirical, smear, RBE, radiosensitivity, ash sample, one-short intake.

Module 2-5, "Personnel Monitoring Devices, Ionization Types."

This module contains a detailed look at the ionizing type personnel monitoring devices. The two common types of dosimeters are illustrated, their structure examined, and the mechanisms for charging and reading the dosimeter is discussed. The precautions and limitations to be observed in using dosimeters are also listed.

Module 2-6, "Personnel Monitoring Devices, Chemical Types."

Chemical types of personnel monitoring devices are looked at in detail. Five different types are examined as to their ability to detect ionizing and neutron radiation, basic operational feature, relative accuracy and speed of use. Guidelines are also provided for the selection of the most practical types to be utilized under given radiation monitoring situations.

COURSE 3, PRINCIPLES OF PROCESS INSTRUMENTATION.

Module 3-1, "Temperature-Sensing Devices: Glass-Bulb Thermometers."

The glass-bulb thermometer as a basic temperature sensing device is discussed as to its operational theory, variety and ability to monitor temperature.

Module 3-2, "Temperature-Sensing Devices: Thermocouples."

This module discusses in detail the operational theory of thermocouples and temperature measurement systems utilizing thermocouples.

Module 3-3, "Temperature-Sensing Devices: Resistance Thermometers."

A detailed presentation concerning the theory and operation of resistance thermometer systems is given.

Module 3-4, "Temperature-Sensing Devices: Pyrometers."

The temperature measuring qualities of an optical pyrometer are listed, and its design and optimum use are detailed.

Module 3-5, "Basic Principles of Flow Measurement."

This module studies the principles of flow and pressure and measurement of each using the proper instruments.

Module 3-6, "Pressure-Sensing Devices."

This module examines the operating characteristics and use of several manometer and mechanical gage type pressure-sensing devices. The devices are compared and contrasted and their optimum use described.

Module 3-7, "Flow-Sensing Devices: Differential Pressure Flowmeters."

The specific characteristics, applications, advantages and disadvantages, installation and maintenance of differential-pressure flow measurement devices are discussed. The terminology related to calibration of the devices is also covered.

Module 3-8, "Flow-Sensing Devices: Linear Flowmeters."

Basic operating principles of primary elements of linear flowmeters and related secondary elements are discussed. The specific characteristics, uses, advantages and disadvantages, installation, alignment (calibration), operation and maintenance are discussed for power plant applications.

COURSE 5, INTRODUCTION TO NUCLEAR SYSTEMS.

Module 5-1, "Basic Nuclear Reactor Components."

Sketches and diagrams are used to illustrate and discuss the components of a light water reactor, reactor vessels, control rod drive systems (PWR and BWR) and fuel assemblies in PWR and BWR systems.

Module 5-2, "Pressurized Water Reactor (PWR)."

This module gives a detailed look at a pressurized water reactor (PWR) including the hydraulic, pneumatic and electrical components. Diagrams and illustrations show their internal structures, and the two basic types of steam generators are illustrated and discussed.

Module 5-3, "Boiling Water Reactor (BWR)."

The boiling water reactor (BWR) is described in detail including its advantages and limitations. Illustrations clearly describe the various systems and components of the BWR. Fuel assemblies, control rods and jet pumps are also described in detail.

Module 5-4, "Primary Cooling Systems."

A brief review of the reactor vessel, pressurizers and steam generators is provided. Detailed mechanisms and design characteristics of reactor coolant pumps, piping, primary systems, valves and insulation is also shown. Overall design specifications and in-service inspection is also discussed.

Module 5-5, "Nuclear Instrumentation."

This module describes in detail the types and components of radiation detectors used to monitor radiation levels in power plants. Four kinds of radiation and associated instruments are listed and discussed as well as back up or fail safe systems for monitors.

Module 5-6, "Nuclear Fuel Cycle."

The complete nuclear fuel cycle is illustrated and described in detail through the following steps: (a) mining, (b) milling, (c) refining, (d) enriching, (e) oxide fabrication, and (f) fuel assembly through reprocessing spent fuel. Plutonium and thorium are also introduced as potential fuels for the future. A visit to a plant involved in one of the steps in the cycle is encouraged.

COURSE 11, RADIATION DETECTION AND MEASUREMENT.

Module 11-1, "Statistics of Radiation Counting."

Radioactivity follows certain predictable patterns which are statistically described through the definitions of (a) radioactive decay, (b) geometry factor, (c) interactions, (d) inverse-square law, (e) dead time, (f) average value, (g) standard error, (h) theoretical standard deviation, (i) standard deviation, and (j) normal distribution. Background radiation and changes in counter geometry are also discussed.

Module 11-2, "Gas-Filled Detectors I: Ionization Detectors."

Three types of ionization detectors including the integrating, nonintegrating and mean-level are described. The module also describes the calculation of current produced by given exposure, ionization chambers and curves, and the details of a pocket dosimeter. Other terms defined in the module include: (a) pulse counter, (b) ion pair, (c) recombination, (d) saturation voltage, (e) saturation current, (f) discriminator, (g) air equivalence, (h) energy dependence, (i) spectroscopy, and (j) efficiency.

Module 11-3, "Gas-Filled Detectors II: Proportional Counters."

This is the second module in a series discussing detectors and describes proportional counters — the five basic types and varieties. Definitions found in the module include: (a) P-10 gas, (b) internal proportional counter, (c) 4π or absolute counter, (d) flow-through counter, (e) discriminator, (f) resolving time, (g) fission counter, (h) proton recoil counter, (i) Hurst counter, and (j) Hurst dosimeter.

Module 11-4, "Gas-Filled Detectors III: Geiger-MÜeller Counters."

This is the third module in the detector series and specifically describes the operating mechanisms of a gas-filled detector using the Geiger counter as an example. Terms discussed and defined include: (a) internal and external quenching, (b) limited proportionality, (c) breakdown voltage, (d) continuous-discharge region, (e) multiple discharge, (f) dead time, (g) recovery time, (h) geometry factor, and (i) self-absorption.

Module 11-5, "Scintillators, Semiconductors and Spectroscopy."

Another class of detectors includes the solid-state devices discussed in this module including the four basic types of scintillation counters and the three categories of semiconductor devices. Also covered are such terms as: (a) photomultiplier tube, (b) luminescence, (c) phosphorescence, (d) activator, (e) photocathode, (f) dynodes, (g) secondary emission ratio, (h) well crystal, (i) p-n junction, (j) depletion layer, (k) GeLi detector, and (l) pulse-height analysis.

Module 11-6, "External Personnel Dosimeters for Beta-Photon Monitoring."

Two major types of dosimeters (namely, photographic and luminescent dosimeters) are discussed and illustrated including the mechanisms for calibration, limitation, and optimum use. Several other items are described including: (a) roentgen, (b) rad, (c) rem, (d) quality factor, (e) latent image, (f) sensitivity, (g) energy dependence, (h) radiophotoluminescence, (i) thermoluminescence, (j) glow curve, and (k) glow peak. The effect of radiation dose is also briefly discussed.

Module 11-7, "Neutron Detectors, Dosimetry and Activation Analysis."

Three major groupings of neutron detectors and their applications are described and the details of a compensated ionization chamber, activation foils, the albedo neutron dosimeter and a fission-fragment dosimeter are included. Neutron activation analysis is also introduced and briefly described.

Module 11-8, "Radiological Calibration and Standardization."

This module examines five aspects of radioactive standardization including: (a) measurement of disintegration rate, (b) mass determination, (c) calorimeter, (d) source preparation and (e) standardized solutions used. Common radioactive standardization sources are discussed and requirements of the National Bureau of Standards also are outlined.

COURSE 14, INTRODUCTION TO QUALITY ASSURANCE/QUALITY CONTROL.

Module 14-1, "Basic Requirements for Quality Assurance/Quality Control in the Nuclear Industry."

This module introduces the topic of QA/QC through a description of: (a) Federal regulatory processes, (b) an overview of QA/QC, (c) other participants in the licensing process, (d) the impact of technical professional organizations on QA/QC, and (e) a listing of the self-regulating mechanisms of the industry.

Module 14-2, "Definitions and Descriptions of Quality Assurance/Quality Control Criteria."

A concise definition of quality assurance and quality control and their differences are given in this module. The meanings of each of the eighteen QA criteria and basic duties of QA/QC personnel are also provided.

Module 14-3, "Governmental Regulation of Quality Assurance/Quality Control (AEC, NRC)."

The historical evolution of the AEC and NRC and their impact on nuclear regulations includes a discussion of Federal Regulation 10CFR50. Also included in this module is a description of the NRC rainbow-colored books which discuss various aspects of QA/QC. Finally, a brief description of the NRC regulatory guides is provided.

Module 14-4, "Technical Regulation of Quality Assurance/Quality Control (ASME, ANSI)."

Section III of the ASME code is examined in detail as is ANSI standard N45-2. The influence of ASTM, IEEE, ACI and AWS on QA/QC is also given.

Module 14-5, "Implementation of Quality Assurance/Quality Control Programs and Procedures."

The parts of the QA/QC manual are described including minimum standards. A method of devising procedures and instruction documents and the contents of the ten parts is also provided. Finally, a note as to the functions of the QA/QC personnel is documented.

Module 14-6, "Application of Quality Assurance/Quality Control to Industry."

This module specifies the five requirements of 10CFR50, ASME code and ANSI standards for quality assurance/quality control which affect: (a) design aspects of materials, components and facilities, (b) manufacturing processes, (c) construction, testing and inspection, and (d) operation and maintenance for nuclear facilities.

Module 14-7, "Techniques and Variations in Quality Assurance/Quality Control."

Three QA/QC establishment procedures are described including user developed, consultant assisted and subcontracted programs. Example forms are provided as indicators of typical tag sheets for QA/QC monitoring.

Module 14-8, "Quality Assurance/Quality Control Records and Documents."

Verification of QA/QC activities is handled through accurate, time documentation of forms shown in this module. Selection of mechanisms for indexing, storage and retrieval of permanent and nonpermanent records through the record control center is also discussed.

Module 14-9, "Special Studies in Quality Assurance/Quality Control."

General QA/QC requirements for technical and quality-assurance specifications are described. Several aspects of QA/QC personnel including: (a) certification, (b) on-the-job training, and (c) seminars, indoctrination programs, and orientations are also outlined. Briefly identified also are six methods of inspections, tests and verifications.

COURSE 15, METALLURGY AND METALS PROPERTIES.

Module 15-1, "Fabrication Processes for Metals."

A basic introduction is given in the fabrication processes for steel from its creation from pig iron to the structural changes resulting from shaping and heat treating. Various tube steel products are also listed.

Module 15-2, "Chemical Analysis of Metals."

This module examines impurities in ferrous metals of primary containment systems which must meet ASME boiler and pressure vessel code requirements. ASTM standards, carbon analysis and emission spectroscopy are also related to the analysis of metal impurities.

Module 15-3, "Basic Metallurgical Concepts."

Several steps are taken to form alloys including the processes of solidification, phases of matter, properties of a solid solution and solid-liquid equilibrium characteristics — all of which are described in this module.

Module 15-4, "Properties of Steel."

Glossary terms needed to understand the hardening properties of steel alloys are listed in this module. The uses of the various steel alloys in power plants are also identified.

Module 15-5, "Metallographic Examination."

Examining metal alloys is done using the unaided eye and the optical reflecting microscope. Preparation of test specimens using proper laboratory procedures to examine the grain structure is also outlined.

Module 15-6, "Mechanical Testing — Tensile, Bend, Hardness."

This module applies the properties of metal testing through three basic tests, namely: (a) tensile, (b) bend, and (c) hardness. The operation of these tests and the interpretation of the test results is also presented. Many of the tests are illustrated and practice exercises allow the application of principles.

Module 15-7, "Mechanical Testing — Impact, Nick Break, Fatigue."

Three mechanical tests of metals including the single blow "impact" test, multiple flexures in the "bend" test and frequently repeated stress applied in the "fatigue" test are illustrated, described and the resultant metal changes are discussed.

Module 15-8, "Failure Mechanisms in Metals."

The various causes of metal failure with an emphasis on the interaction of various types of radiation with different classes of material are detailed in this module.

COURSE 16, MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS.

Module 16-1, "Pump Characteristics and Specifications."

The description, function, characteristics and various types of pumps needed in a reactor are identified in this module. Various pressure-flow characteristics are also presented.

Module 16-2, "Piping Characteristics and Specifications."

This module examines the various materials used in pipes, their specifications, functions, joining methods, inspection schedules and types of expansion joints commonly used.

Module 16-3, "Valve Characteristics and Specifications."

Several types of valves used in power plants including their description, specifications, operation mechanisms are illustrated and discussed in this module.

Module 16-4, "Fastener Characteristics and Specifications."

Common types of fasteners used, especially nuts and bolts, studs of various materials, and thread standards form the text for this module.

Module 16-5, "Lifting and Handling Equipment Characteristics and Specifications."

Basic handling equipment such as cranes, hoists and conveyors are described and illustrated. Characteristics, specifications and limitations are also listed.

Module 16-6, "Rotating Equipment Characteristics and Specifications."

This module examines all types of rotating equipment such as motors, blowers, generators and turbines (but not pumps) and lists specifications, functions, and general descriptions of each.

Module 16-7, "Heat Exchanger Characteristics and Specifications."

The common types of heat exchangers, their function, description and specifications, including materials and thermal/hydraulic characteristics, are provided in this module.

Module 16-8, "Pressure Vessel Characteristics and Specifications."

Pressure vessel function, description and specification such as materials, types and thermal/hydraulic characteristics are outlined and discussed in this module.

COURSE 26, NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I.

Module 26-1, "Visual Tests."

This module introduces direct, remote, and translucent visual examinations. The following visual examination techniques and procedures are discussed: (a) illumination, (b) surface condition and preparation, (c) usually discernable attributes, (d) sequencing of inspection operations, (e) tabulation of data, and (f) reports.

Module 26-2, "Leak Tests."

This module explores (a) fundamentals of leak testing, (b) safety considerations, (c) testing, (d) safety, (e) standards, (f) procedure selection, (g) the bubble test, (h) the pressure change/measurement test, (i) the halogen diode detector leak test, (j) the mass spectrometer leak test, and (k) a review of SNT-TC-1A technician certification requirements.

Module 26-3, "Hydrostatic Tests."

This module includes (a) an introduction, (b) fundamentals of hydrostatic testing, (c) safety studies, (d) standards for calibration, (e) test equipment and media standards, (f) testing methods, (g) procedure applicability, and (h) interpretation of test results.

Module 26-4, "Liquid Penetrant."

Among the topics discussed are (a) fundamentals of liquid penetrant testing, (b) penetrant methods and materials, (c) test specimen surface preparation, (d) test procedure and techniques, (e) effects of specimen configuration, (f) evaluation of test results, (g) procedure requirements, and (h) certification requirements.

Module 26-5, "Fundamentals of Radiography."

First, a refresher on radiation detection and measurement is given, together with a study of radiation sources. These studies pave the way for an analysis of the following: (a) Geometric principles and applications. (b) Shielding. (c) Radiographic film. (d) Radiographic quality (contrast, sharpness, screens, sensitivity, penetrameters, identification, filters). (e) Advantages and disadvantages. (f) Terms.

Module 26-6, "Radiograph Inspection."

Included in this module are discussions of (a) source selection, (b) film selection and preparation, (c) safety, (d) subject exposure calculations and control, (e) exposure arrangements, (f) film processing and (g) unsatisfactory radiographics — their causes and corrections.

Module 26-7, "Radiographic Specifications and Code Requirements."

General aspects of radiographic film interpretation are presented, together with specific studies of (a) discontinuities in materials, (b) acceptance standards, (c) radiograph evaluation and (d) procedure requirements.

COURSE 27, METROLOGY.

Module 27-1, "Fundamentals of Metrology."

Units of measurement, measurement equipment, sensitivity, accuracy and related items are explored. The role of standards is explained. Sources of errors are discussed.

Module 27-2, "Fixed Gages, Dividers, Calipers and Micrometers."

Each measuring device listed in the module title is described according to use and sources of measurement errors. The interpretation of the Unified System of thread designators is outlined.

Module 27-3, "Gage Blocks, Mechanical Comparators and Electronic Comparators."

Four tolerance grades of gage blocks are introduced, together with the applications of each. Also discussed are the effects of temperature upon measurements, comparative measurement, Abbe's law, sources of error, cosine error, etc.

Module 27-4, "Angle Measurement Instruments, Optical Projectors and Surface Texture Gages."

Among the subtopics covered are the operation, measurement and sources of error of the universal bevel protractor, the sine bar, the engineering microscope, and the optical projector. The effects of surface texture are explored.

Module 27-5, "Tolerancing."

The following terms are defined: maximum material condition, least material condition, straightness, flatness, roundness, cylindricity, perpendicularity, parallelism, true position, concentricity and runout. The interpretation of drawings requirements for bilateral, unilateral and limit tolerancing is explained.

Module 27-6, "Calibration."

The calibration program is described in terms of tolerance-to-accuracy ratio, traceability, accuracy, interval, verification, causes of instruments being out of calibration, standards, etc.

Module 27-7, "Statistical Techniques in Metrology."

This module describes the general responsibilities of the QA/QC technician operating at a nuclear plant construction site. Other topics discussed are measurement cells, frequency distribution, mean and standard deviation, risks associated with sampling procedures, and acceptance and rejection criteria.

Module 27-8, "The Total Measurement System."

Among the topics discussed are (a) differentiation between inspection and inspectability, (b) the role of inspection staging, (c) criteria for inspection staging, (d) the purpose of inspection policies and procedures, and (e) inspection instructions.

COURSE 28, WELDING INSPECTION

Module 28-1, "Welding Fundamentals and Processes."

A study is made of the following topics: joint, heat source, distortion control, filler material, shielding, techniques, defects, oxyacetylene, shielded metal arc, tungsten inert gas, metal inert gas, and submerged arc.

Module 28-2, "Shielded Metal Arc and Oxyacetylene Welding."

For both of these methods, an analysis is made of (a) equipment used, (b) process techniques and procedures, (c) essential variables, (d) characteristic defects and their causes and prevention, and (e) types of inspection.

Module 28-3, "Tungsten Inert Gas (TIG), Metal Inert Gas (MIG) and Submerged Arc Welding."

These three welding processes are presented under the categories of (a) equipment used, (b) process techniques and procedures, (c) essential variables, (d) characteristic defects and their causes and prevention and (e) types of inspections.

Module 28-4, "Weld Joint Verification."

This module examines (a) joints such as butt, corner, tee, lap, and hardsurfacing; (b) weld joint preparations such as squared, single bevel groove, V-groove, U-groove, J-groove, and fillet; (c) weld joint fit-up with respect to cleanness, alignment, root gap, backing rings, and consumable inserts; and (d) verification inspection.

Module 28-5, "Qualifications."

Topics include (a) welding procedure qualification; (b) welder and welding operator performance qualification; (c) procedures and essential variables, including weld procedure specification, joint design, base metals, filler materials, positions, preheat, post-weld heat treatment, electrical characteristics, and technique; and (d) requalification requirements.

Module 28-6, "Process Controls."

Among the areas explored are the following: (a) Inspection related to preparation for welding: preparation of base material and grinding, joint fill-up and grinding, base material type and cleanliness, filler material, and confirmation of qualifications. (b) Inspections related to welding: tack, root pass, and intermediate layers; reverse side; final weld; process control. (c) Postweld heat treatment.

Module 28-7, "Acceptance Inspection."

Inspection is discussed with respect to the relationship of weld classification with inspection methods of internal and surface defects. The sequence of inspection is explained, as well as acceptance criteria and the relationship of inspection results to defects and their causes.

Module 28-8, "Filler Material Control."

The essential elements of control are presented; they include identification (classification), certification, traceability, segregation, and cleanliness and moisture control. Material flow path handling is examined and includes receiving, storage and issue, welding station, and disposal or return to storage. Inspection procedures are included.

Module 28-9, "Weld Repair Control."

Discussion topics include (a) repair classification (major and minor), (b) inspections prior to repair, (c) repair process (including dimensional control) and (d) inspections after repair.

Module 28-10, "Records."

The types of records discussed are (a) weld joint history records, (b) destructive tests and (c) nondestructive tests. Records are analyzed according to category and purpose as follows: (d) procedure qualification records, (e) performance qualifications recods, and (f) record storage and retrievability.

COURSE 29, CIVIL/STRUCTURAL INSPECTION.

Module 29-1, "Inspection of Construction Operations."

Methods for calculating allowable concrete variations relating to batching water, cement and aggregates are presented. Other related topics include the types and functions of concrete forms, steel reinforcing practices, concrete placement and curing, form removal, surface finishing, structural fill, and soils testing.

Module 29-2, "Structural Steel Materials, Installation and Inspection."

This module describes (a) the materials used in structural steel work; (b) the standards to which materials are purchased and inspected; (c) fabrication, handling and installation practices; and (d) the various inspection tasks performed during erection operations.

Module 29-3, "Concrete Materials."

Topics discussed include (a) characteristics of different types of cement; (b) handling and storage of cements, aggregates, admixtures, and reinforcing steels; (c) the chemical reactions caused by aggregate; and (d) the function of reinforcing steel and its identity marking scheme.

Module 29-4, "Concrete Preparation, Production, Placement and Finishing."

Standards must be met and records maintained for the concrete operation. Concrete mix proportions must be monitored carefully. This module covers these areas, as well as such projects as grouting operations, construction joints, and concrete finishing and cleanup.

Module 29-5, "Concrete Testing and Inspection."

This module explains testing techniques and equipment utilized for such tests; the discussion includes (a) sampling, (b) tests for concrete consistency, (c) air content compressive strength, and (d) analysis of test data.

Module 29-6, "Prestressed Concrete Materials, Fabrication and Inspection."

Three basic methods for the prestressing of concrete members are presented. Tendons and tendon ducts also are presented. Methods of tendon de-tensioning and pre-tensioning are outlined.

COURSE 30, MECHANICAL INSPECTION.

Module 30-1, "Pump Inspection."

The following inspection procedures are explained: (a) Pre-installation verification, (b) installation process control, (c) pre-operational testing and inspection and (d) documentation.

Module 30-2, "Pump Function Testing."

Pre-operational testing is reviewed; then cold function testing is studied as it relates to reactor coolant system hydrostatic testing and to function and flow. Hot function testing is an important part of the module.

Module 30-3, "Valve Inspection."

Topics: Pre-installation verification, installation, functional inspections and tests, and documentation.

Module 30-4, "Piping Inspection."

Topics: Pre-installation verification, installation, functional inspections and tests, and documentation.

Module 30-5, "Surface Cleaning Inspection."

The criteria for cleaning are defined. Methods are given for pre-installation, installation pre-operational, and layup and post-layup cleanness.

Module 30-6, "Protective Coating Inspection."

Among the topics discusses are (a) qualifications of coating inspection personnel, (b) dry film thickness of coatings, (c) coating inspection equipment, (d) deviation and remedial actions and (e) documentation.

Module 30-7, "Pressure Vessel Inspection."

An introduction is given for pressure vessel fabrication and design. Methods are outlined for destructive and nondestructive examinations of pressure vessels.

Module 30-8, "Rotating Equipment Inspection."

This module explains the following items: (a) Preconstruction verification, including identification, physical conditions, and site conditions. (b) Installation controls, including worksite and work-in-progress inspections. (c) Installed systems inspection and tests, including pre-operational and hot and cold functional tests.

COURSE 31, QUALITY-ASSURANCE PRACTICES.

Module 31-1,"Overall Quality Assurance Program."

This module discusses the standards for implementation of regulatory requirements and relates the application of ANSI quality assurance standards to the design, construction and operations phases of nuclear power plants.

Module 31-2, "Vendor Qualification."

This module discusses the purchaser's program for selection of procurement sources, including the methods of quality history, current quality information and on-site review. Bid evaluation is related as it applies to technical considerations, quality assurance, supplier personnel, supplier production capacity, expectations, and purchaser's verification.

Module 31-3, "Receiving Inspection."

Topics: (a) The relative responsibilities for the receiving activity of Material Services department, Quality Assurance, and Quality Control. (b) Inspection for damage and for quality. (c) Paperwork (forms and other documentation.)

Module 31-4, "Identification, Storage and Handling of Components, Parts and Materials."

The categories of protection (A, B, C, and D) for products are detailed. Features of different packaging are presented; the following packaging methods are explained: barriers, dessicants, caps and plugs, containers, inert gas blanket, contact preservative, blocks, braces and cushions.

Module 31-5, "Nonconforming Material."

These terms are defined as they apply to the nonconforming material control system: nonconformance, identification, documentation, segregation, disposition and notification. A description is made of the types of information typically documented by the nonconformance report.

Module 31-6, "Certification and Qualification of Quality-Control Inspectors."

A general description is given of the educational, experience and examination prerequisites for qualification, including the relationship of educational level, training courses, and on-the-job experience.

Module 31-7, "Auditing for Quality Assurance."

Topics: (a) Qualifications of auditors and lead auditors. (b) Internal and external audits. (c) Elements of the audit system. (d) Audit schedules, preparation tasks, and performance tasks. (e) Audit reports. (f) Follow-up actions by both the audited and auditing organizations.

Module 31-8, "Document Handling, Storage and Retrieval for Quality Assurance."

The two classifications of records required by the Nuclear Regulatory Commission are described; the significance of each with respect to records storage is explained. The role of separate, remote, duplicate areas for record storage is emphasized.

COURSE 32, NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES II.

Module 32-1, "Fundamentals of Ultrasonic Testing."

Topics: (a) Principles of ultrasonic wave behavior. (d) Description of ultrasonic test equipment and use. (c) Ultrasonic testing methods and instruments, including the resonance, intensity, pulse, and transit time methods.

Module 32-2, "Operation of Ultrasonic Testing."

Topics: (a) Principles of ultrasonic instrument operation. (b) Testing techniques and interpretation of results, including probe selection and coupling, instrument calibration, flow detection, flow level, flow position and shape, determination of thickness and velocity, special testing problems on non-metals, special testing problems on flow detectability versus flow shape and orientation.

Module 32-3, "Fundamentals of Magnetic Particle Testing."

Topics: (a) Principles of magnets and magnetic fields. (b) Effects of discontinuities on materials. (c) Magnetization of test specimens. (d) Test equipment. (e) Principles of demagnetization. (f) Applicability of magnetic particle test methods. (g) Advantages and disadvantages of M.T. test methods.

Module 32-4, "Operation of Magnetic Particle Test Equipment."

Topics: (a) Operation of test equipment. (b) Types of discontinuities detected, test indications and interpretation; discontinuities discussed are non-metallic inclusions, surface seams, cracks, laminations, laps, bursts and flakes, porosity, and non-relevant indications.

Module 32-5, "Fundamentals of Eddy Current Testing."

Topics: (a) Principles of eddy current generation and behavior. (b) Description of eddy current testing and use. (c) Eddy current testing methods, including conductivity, discontinuity, and thickness testing. (d) Review of SNT-TC-IA technician certification requirements.

Module 32-6, "Operation of Eddy Current Test Equipment."

Topics: (a) Principles of operation of eddy current testing equipment. (b) Testing techniques and interpretations of results, including coil selection and calibration and flow detection and interpretation. (c) Advantages and disadvantages of test methods.

Courses being developed for the other curricula in the Nuclear Technology series (see chart on Page 12) follow:

COURSE 4: HEAT TRANSFER AND FLUID FLOW.

Module 4-1: Basic Properties of Fluids.
Module 4-2: Fluid Statics.
Module 4-3: Fluid Dynamics.
Module 4-4: Heat Transfer by Conduction.
Module 4-5 Heat Transfer by Convection.
Module 4-6: Heat Transfer by Radiation.
Module 4-7: Change of Phase – Boiling.
Module 4-8: Burnout and Flow Instability.
Module 4-9: Reactor Heat Transfer Limits.

COURSE 6: INSTRUMENTATION AND CONTROL OF REACTORS AND PLANT SYSTEMS.

Module 6-1: Neutron Monitoring Systems.
Module 6-2: Neutron Sensors.
Module 6-3: Neutron Flux Signal Conditioning.
Module 6-4: Control-Rod Drives and Indicating Systems.
Module 6-5: Instrumentation Power Supplies.
Module 6-6: Installation of Instrumentation Systems.

COURSE 7: REACTOR OPERATIONS.

Module 7-1: Reactor Operator Licenses.
Module 7-2: Administrative Control for Nuclear Systems.
Module 7-3: Reactor Operating Experiences.
Module 7-4: Reactor Startup Procedures.
Module 7-5: Pressurized Water Reactor Operating Characteristics.
Module 7-6: Boiling Water Reactor Operating Characteristics.
Module 7-7: Refueling of Reactors.

COURSE 8: REACTOR SAFETY.

Module 8-1: Introduction to Reactor Safety.
Module 8-2: Reactor Licensing.
Module 8-3: Reactor Protection Systems.
Module 8-4: Reactor Emergency Systems.
Module 8-4: Safeguards and Security.

COURSE 9: REACTOR AUXILIARY SYSTEMS.

Module 9-1: Containment and Ventilation of Reactors.
Module 9-2: Spent Nuclear Fuel Storage and Handling Procedures.
Module 9-3: Emergency Power Systems for Reactors.
Module 9-4: Residual and Emergency Cooling Systems for Reactors.

COURSE 10: POWER PLANT SYSTEMS.

Module 10-1: Power Plant Fundamentals.
Module 10-2: Power Plant Thermal Cycles.
Module 10-3: Turbines and Generators.
Module 10-4: Heat Exchangers and Condensers.
Module 10-5: Pumps.
Module 10-6: Valves and Piping.
Module 10-7: Electrical Transmission and Distribution Systems.
Module 10-8: Power Plant Fundamentals (Fossil Fuel Energy Efficiency).
Module 10-9: Fossil Plant: Auxiliary Discussions.

COURSE 12: REACTOR PHYSICS.

Module 12-1: Neutron Physics.
Module 12-2: Cross Sections and Reactions.
Module 12-3: Fission Rate and Reactor Plant.
Module 12-4: Time Independent Nuclear Theory.
Module 12-5: Time Dependent Nuclear Theory.
Module 12-6: Reactivity – Fuel Moderator and Control Systems.
Module 12-7: Internal Effects on Reactivity.
Module 12-8: Reactor Operating Characteristics.

COURSE 13: POWER PLANT CHEMISTRY.

Module 13-1: Water Quality Control.
Module 13-2: Raw Water Treatment.
Module 13-3: Sources of Impurities in Reactor Water Systems.
Module 13-4: Water Treatment – Polishing by Ion Exchange, Evaporation and Demineralization.
Module 13-5: Water Properties Sensing.
Module 13-6: Water Analysis for Nuclear Power Plants.
Module 13-7: Radioactive Waste Handling – Liquid and Gaseous.

COURSE 17: RADIATION PROTECTION II.

Module 17-1: Film Dosimetry.
Module 17-2: Thermoluminescent Dosimetry (TLD).
Module 17-3: Radiation Dose Assessment – Personnel Dosimeters.
Module 17-4: Internal Dose Assessment.
Module 17-5: Bioassay Techniques and Record Keeping for Radiation Protection.

COURSE 18: RADIOLOGICAL EMERGENCIES.

Module 18-1: General Procedures for Radiological Emergencies.
Module 18-2: Emergency Equipment for Nuclear Facilities.
Module 18-3: Surface Contamination – Decontamination.
Module 18-4: Criticality Control.
Module 18-5: Control of Radiological Hazards.
Module 18-6: Emergency Planning for Nuclear Facilities.
Module 18-7: Emergency Drills for Nuclear Facilities.

COURSE 19: RADIATION SHIELDING.

Module 19-1: General Effect of Radiation Attenuation.
Module 19-2: Beta and Alpha Particle Attenuation.
Module 19-3: Neutron Attenuation.
Module 19-4: Gamma Attenuation.
Module 19-5: Background Radiation Reduction Techniques.
Module 19-6: Backscattering and Wall Scattering of Radiation.

COURSE 20: RADIATION MONITORING TECHNIQUES (RADIOCHEMICAL).

Module 20-1: Radiation Sample Preparation – Liquid.
Module 20-2: Radiation Sample Preparation – Solid.
Module 20-3: Air Monitoring Techniques – Particulate.
Module 20-4: Air Monitoring Techniques – Gaseous.
Module 20-5: Water Monitoring Techniques – Dissolved Solids.
Module 20-6: Water Monitoring Techniques – Suspended Solids.
Module 20-7: Radiation Monitoring of Biological Samples.

COURSE 21: RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT.

Module 21-1: Waste Disposal Procedures. (Same as Module 25-6.)
Module 21-2: Routine Sampling of Radioactive Waste.
Module 21-3: Waste Disposal Regulations.
Module 21-4: Measurement of External Radioactive Contamination. (Same as Module 25-8.)
Module 21-5: Regulations for Transporting Radioactive Materials.
Module 21-6: Packaging and Monitoring of Radioactive Materials for Shipment. (Same as Module 25-7.)
Module 21-7: Leak Tests for Sealed Radioactive Sources.

COURSE 22: ADVANCED RADIONUCLIDE ANALYSIS.

Module 22-1: Survey of Methods Used in Radionuclide Analysis (Sample Collection & Analysis.)
Module 22-2: Gamma Spectrometry.
Module 22-3: Alpha Spectrometry.
Module 22-4: Beta Spectrometry.
Module 22-5: Radiochemical Methods of Analysis by Liquid Scintillation Counting.
Module 22-6: Neutron Activation Analysis.
Module 22-7: Determination of Specific Nuclides (In the Environment).

COURSE 23: NUCLEAR CHEMICAL PROCESSES.

Module 23-1: Head-End Treatment.
Module 23-2: Ion Exchange.
Module 23-3: Solvent Extraction.
Module 23-4: Precipitation Techniques and Centrifugation.
Module 23-5: Techniques of Chemical Concentration.
Module 23-6: Diffusion and Enrichment Process.
Module 23-7: Nuclear Waste Handling Processes.

COURSE 24: NUCLEAR SYSTEMS AND SAFETY.

Module 24-1: Neutron Physics. (Same as Module 12-1.)
Module 24-2: Cross Sections and Reactions. (Same as Module 12-2.)
Module 24-3: Fission Rate and Reactor Power. (Same as Module 12-3.)
Module 24-4: Nuclear Criticality.
Module 24-5: Nuclear Material Inventory Management Techniques.
Module 24-6: Nuclear Plant Safeguards.

COURSE 25: RADIOACTIVE MATERIAL HANDLING TECHNIQUES.

Module 25-1: Glove Box Operations – Fundamentals.
Module 25-2: Glove Box Operations – Advanced.
Module 25-3: Master/Slave Manipulator – Fundamentals.
Module 25-4: Master/Slave Manipulator – Advanced.
Module 25-5: Remote Sampling Techniques.
Module 25-6: Waste Disposal Procedures. (Same as Module 21-1.)
Module 25-7: Packaging and Monitoring of Radioactive Materials for Shipment. (Same as Module 21-6.)
Module 25-8: Measurement of External Radiation Contamination. (Same as Module 21-4.)

COURSE 33: CONTROL SYSTEMS I.

Module 33-1: Introduction to Block Diagrams.
Module 33-2: Input/Output Devices.
Module 33-3: Control System Theory.
Module 33-4: Pneumatic Control Mechanisms.
Module 33-5: Control Valves.
Module 33-6: Process Control Characteristics.

COURSE 34: CONTROL SYSTEMS II.

Module 34-1: Introduction to Transfer Functions.
Module 34-2: Frequency Response Analysis.
Module 34-3: Combination Control Systems.
Module 34-4: Controller Tuning.
Module 34-5: Operational Amplifiers.
Module 34-6: Microprocessor Utilization.
Module 34-7: Microprocessor Programming.

COURSE 35: POWER PLANT ELECTRICAL SYSTEMS AND COMPONENTS.

Module 35-1: Electrical Distribution.
Module 35-2: Instrumentation and Control for Major Plant Components.
Module 35-3: Recording and Display Devices.
Module 35-4: Process Control Loops and Devices.
Module 35-5: Cathode Ray Tube Systems (CRT).
Module 35-6: Preventive Maintenance for Systems and Components.
Module 35-7: Instrument Reliability.

APPENDIX C

SUGGESTED WORKFORCE NEEDS SURVEY INSTRUMENT FOR NUCLEAR QA/QC TECHNICIANS

Dear Sir:

I am writing to ask for your help. Our school is considering the establishment of a 2-year technical program in the new field of nuclear power plant operation. Prior to establishing such a program, I have been asked to conduct a survey of the present and future needs in this locale for technicians with this special training. I have enclosed the survey, which should take just a few minutes to complete. When you are done, simply place this survey in the enclosed stamped addressed envelope and return. If you wish a copy of the results of the survey, please so indicate at the end of the questionnaire.

If, for some reason, this questionnaire does not apply to your specific area of responsibility at your organization, please pass it on to someone to whom it may be more appropriate.

I appreciate your efforts in behalf of this new occupational training program in the state.

Sincerely,

_____
Title

TYPICAL WORKFORCE NEEDS SURVEY INSTRUMENT FOR NUCLEAR QA/QC TECHNICIANS

Name of company, institution, or government division:

_____

_____

Definition: A Quality Assurance/Quality Control Technician performs tests, inspections, checks, and audits to assure that a facility, component, or activity has been fabricated, installed, operated, and maintained in accordance with drawings and specifications.

	Yes	No	
1.	_____	_____	Does your company currently employ QA/QC Technicians?
2.	_____	_____	Doe you have current vacancies for QA/QC technicians?

3. Please indicate the typical beginning salary a Nuclear QA/QC Technician might expect to receive in your company.

a. $700-800/mo. _____
b. $801-1000/mo. _____
c. $1001-1200/mo. _____
d. $1201-1400/mo. _____
e. $1401-1600/mo. _____
f. Greater than $1500/mo. _____

4. In your opinion, your need for Nuclear Reactor QA/QC Technicians during the next ten years will:

_____ decrease
_____ remain the same
_____ increase by 0-25%
_____ increase by 26-50%
_____ increase by 51-75%
_____ increase by 76-100% or more

5. Can you give an estimate of the total number of Nuclear QA/QC Technicians you will need in the next five year period?

1980 _____
1981 _____
1982 _____
1983 _____
1984 _____

6. As you employ Nuclear QA/QC Technicians in the future, would you:

_____ prefer to train these individuals yourself?
_____ prefer to hire individuals trained in nuclear plant fundamentals in a recognized and approved institution?

7. Please circle those items in which you think the Nuclear QA/QC Technician should receive specific training:

I. Radiation Physics.
II. Radiation Protection.
III. Process Instrumentation.
IV. Introduction to Nuclear Systems.
V. Instrumentation and Control of Reactors and Plant Systems.
VI. Radiation Detection and Measurement.
VII. Metallurgy and Metals Properties.
VIII. Characteristics and Specifications of Mechanical Components.
IX. Nondestructive Examination (NDE) Techniques.

Visual tests.
Leak tests.
Hydrostatic tests.
Liquid penetrant.
Fundamentals of radiography.
Radiograph inspection.
Radiographic specifications and code requirements.

X. Metrology.

Fundamentals of metrology.
Fixed gages, dividers, calipers and micrometers.
Gage blocks, mechanical comparators and electronic comparators.
Angle measurement, optical projectors and surface texture gages.
Tolerancing.
Calibration of metrology instruments.
Statistical techniques in metrology.
The total measurement system.

XI. Welding Inspection.

Welding fundamentals and processes.
Shielded metal arc and oxyacetylene welding.
Tungsten inert gas (TIG), metal inert gas (MIG) and submerged arc welding.
Weld joint verification.
Qualifications.
Process controls.
Acceptance inspection.
Filler material control.
Weld repair control.
Records.

XII. Civil/Structural Inspection.

Inspection of construction operations.
Structural steel materials, installation and inspection.
Concrete materials.
Concrete preparation, production, placement and finishing.
Concrete testing and inspection.
Prestressed concrete materials, fabrication and inspection.

XIII. Mechanical Inspection.

Pump inspection.
Pump functional testing.
Valve inspection.
Piping inspection.
Surface cleaning inspection.
Protective coating inspection.
Pressure vessel inspection.
Rotating equipment inspection.

XIV. Quality-Assurance Practices.

Overall quality assurance program.
Vendor qualification.
Receiving inspection.
Identification, storage and handling of components, parts and materials.
Nonconforming material.
Certification and qualification of quality-control inspectors.
Auditing for quality assurance.
Document handling, storage and retrieval for quality assurance.

XV. Advanced Nondestructive Examination (NDE).

Fundamentals of ultrasonic testing.
Operation of ultrasonic test equipment.
Fundamentals of magnetic particle testing.
Operation of magnetic particle test equipment.
Fundamentals of eddy current testing.
Operation of eddy current test equipment.

8. Due to specific duties, titles for a Nuclear Quality Assurance/Quality Control Technician may vary; which of the following titles are used by your company to describe these individuals?

_____ Civil/Structural Inspector (or Technician).
_____ Mechanical Quality Control Inspector (or Technician).
_____ Electrical Quality Control Inspector (or Technician).
_____ NDE Inspector (or Technician).
_____ Welding Quality Control Inspector (or Technician).
_____ Other (specify) _____

9. Would you classify your company's principal endeavor as:

_____ Electrical power production.
_____ Research and development.
_____ Nuclear materials processing and disposal.

____ Equipment manufacturer.

____ QA/QC contract work.

____ Other (specify) _____

10. Comments: Please include any additional information which you feel would help us identify the need in numbers and competencies for Nuclear QA/QC Technicians.

_____

_____

_____

_____

	Yes	No	
11.	____	____	Would you like to receive a copy of the report summarizing the results of this survey?

Please mail to: _____

_____

_____

_____

Your kind assistance in completing this survey questionnaire is appreciated.

APPENDIX D

UNIVERSITIES WITH RESEARCH REACTORS

Brigham Young University (L-77)
California State Polytechnic College (AGN-201)
Catholic University (AGN-101)
Columbia Univeristy (TRIGA)
Cornell University – Zero Power Reactor (ZPR)
Cornell University (TRIGA)
Massachusetts Institute of Technology (CP-5)
Michigan State University (TRIGA)
North Carolina State University (Polstar)
Ohio State University
Oregon State University (TRIGA)
Penn State University (TRIGA core)
Purdue University
Reed College (TRIGA)
Rhode Island (AEC)
State University of New York (PULSTAR)
Stanford University
Texas A & M (TRIGA)
Texas A & M (ANG-201M)
Tuskegee Institute (AGN-201)
University of Arizona (TRIGA)
University of California at Irvine (TRIGA)
University of California at Los Angeles (Argonaut)
University of California at Santa Barbara (L-77)
University of Delaware (AGN-201)
University of Florida (Argonaut)
University of Illinois (TRIGA)
University of Illinois (LPRA)
University of Kansas
Georgia Institute of Technology (CP-5)
Idaho State University (AGN-201)
Iowa State University
Kansas State University (TRIGA)
University of Lowell
Manhattan College
University of Maryland (TRIGA)
University of Michigan
University of Missouri at Rolla
University of Missouri at Columbia
University of New Mexico (AGN-201)
University of Oklahoma (AGN-201)
University of Texas (TRIGA)
University of Utah (AGN-201)
University of Virginia (Pool)
University of Virginia (Cavalier)
University of Washington
West Virginia University
University of Wisconsin (TRIGA core)
Virginia Polytechnic Institute
Washington State University (TRIGA core)
Worcester Polytechnic Institute
Memphis State University (AGN-201)

APPENDIX E

EQUIPMENT LIST WITH COST, QUANTITY AND VENDOR DATA

COURSE	TYPE OF EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
	RADIATION			
1	Alarm monitor	475	1	475
1	Chart of the Nuclides	3	3	9
1;27	Coats, white knee-length lab (disposable)	64/25	50	128
6	Compensated ion chamber	620	1	620
6	Uncompensated ion chamber	620	1	620
1;26	Dosimeters, direct reading pocket	80	48	3,840
1	Dosimeter charger	65	5	325
11;26	Dosimetry film (Type NTA and Type 3)	75/box	1 box each	150
1;11;26	Dosimeter, thermoluminescent (TLD)			
	Calibration source	600	1	600
	Holder	8	72	576
	Muffle furnace	700	1	700
	Reader	5,700	1	5,700
	TLD chips (LiF) TLD 100	100/10	240	2,400
	Forceps	1	25	25
11	Electrometer	300	1	300
1	Film badge	10/ass't	1 ass't	10
1	Gloves, disposable rubber or plastic	15/100 pr	500 pr	75
2	Ionization counter, 2π, gas flow type	1,500	2	3,000
11	NaI (T_2) crystals with photomultiplier and pre-amplifier	250	12	3,000
6	Neutron detector	1,100	1	1,100
6	Neutron source (available from DOE for cost of shipping		1	
1;2;5;26	Radioactive sources in exempt quantities	850	1 ass't	850
2;26	Ratemeter, ion chamber	600	12	7,200
1;5;11	Scaler-Ratemeter	1,500	12	18,000
1;11	G-M detector, end-window	125	12	1,500
	side-window	75	12	900
1	Shoe covers (disposable)	3/pr	48 pr	144
1	Storage container for rad waste	275	1	275
11	Survey meter, ion chamber	660	2	1,320
5;6	Survey meter, neutron with BF_3 detector	1,220	2	2,440
1;11;26	Survey meter, portable	600	12	7,200
	Work bench modules			
	Decay cabinet	1,300	12	15,600
	Sink and waste	1,850	12	22,200
	Storage	3,000	12	36,000
	DIMENSIONAL			
27	Bevel protractor, 24"	30	12	600
15;26	Calipers, vernier	35	12	420
15;26	Dividers, fine point	17	12	204
30	Dry film thickness gage	800	1	800
27	Fixed gages	20	12	240
27	Gage block set, grade 2	875	1	875
27	Gage block set, grade 3	1,850	1	1,850
	Meter stick	3	12	36
27	Micrometer:			
	inside	275	6	1,650
	outside	65	6	390
	depth	125	6	750
	thread	85	6	510
27	Parallel bar	400	2	800
26	Radius gage	60	6	360
27	Sine bar	350	2	700
27	Steel rule	15	12	180
30	wet film thickness gage	800	1	800
27	Wood rule	2	12	24

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
	TEMPERATURE MEASUREMENT			
3	Resistance temperature detector:			
	open wire element, 100	725	1	725
	standard platinum, 100	725	1	725
3	Temperature recorder	720	1	720
15	Thermocouples	20	24	480
3;27	Thermometers			
	General laboratory	40/5	ass't	120
	NBS 2° standard total immersion	740	1	740
	NBS test thermometer	26	12	312
26	Temperature-indicating crayons	96/set	2 sets	192
27;26	Pyrometer, contact	225	2	450
3	Wire:			
	Copper, lead	2.50/ft	250 ft	625
	Thermocouple	160/50	50 ft	160
	HARDWARE			
3	Pipe and assorted fittings, galvanized	100	1 ass't	100
3	Tubing:			
	Glass	68/25#	50#	136
	Plastic	175/50 ft	100 ft	350
3;5;30	Valves: Air vent, butterfly, check, diaphragm, gate, globe, motor actuated, plug, Y-pattern, 3-way, 4-way, needle	200	1 ass't	200
	ELECTRICAL			
32	Black light lamp	175	1	175
3	Decade resistance box (5 place)	125	1	125
32	Light meter	125	1	125
32	Magnaflux tester	15,000	1	15,000
3	Millivoltmeter (0-50 mV)	200	12	2,400
1;6;32	Oscilloscope, cathode-ray	1,500	1	1,500
3;15	Potentiometer, dial type	600	1	600
32	Ultrasonic transducer	1,500	1	1,500
	MECHANICAL			
27	Air pump	50	1	50
15	Analyzer, Leco 50-second carbon (pulse height)	1,400	1	1,400
3	Barometer, mercury	280	1	280
5	Centrifugal pump, approximately 30 gpm	450	1	450
32	Eddy-current test instrument	2,000	1	2,000
15	Emery papers grades 0-000	25	12 sets	300
3;15	Flow meter, rotating turbine	325	1	325
3;27	Gages:			
	Hydraulic press and pressure	95	1	95
	Instrument-air			
	High-volume	750	1	750
	Low-volume	750	1	750
	Pressure	75	2	150
26	Helium gas bottle	95	1	95
27;32	Indicators:			
	dial, assortment	300	1 ass't	300
	magnetic field	150	1	150
15	Induction furnace	425	1	425
3	Manometer, 30" U-tube	85	2	170
15	Molder, plastic, for metal specimen preparation	150	1	150
3	Orifice plates	8	3	24
15	Oxygen gas bottle	95	1	95
15	Polish, cerium oxide; tin oxide	58	1 each	116

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
15	Polishing lap	25	1	25
15	Polishing machine, vibratory	600	1	600
32	Probe:			
	Differential bore	400	1	400
	Absolute surface	400	1	400
	AUXILIARY			
1	Absorbers, aluminum and lead	180/set	6	1,080
27	Auto collimator	6,000	1	6,000
15	Balance, analytical	1,300	2	2,600
3;30	Beaker, with spout, 50-100 ml sizes	110/set	12 sets	1,320
26	Bell Jar	75	1	75
30	Buret, 50 ml	85/4	12	255
3	Centrifuge	395	1	395
3	Dessicator	70	6	420
15	Files, flat fine	6	12	72
11	Filters, low Z	10	36	360
3	Flask:			
	Dewar with holder	180/6	5	180
	Erlenmyer, 50-500 ml sizes	80/set	12 sets	960
27;28	Goggles, welder	15	24	360
1;3	Holder, sample	85	12	1,020
15;27	Microscope, metallurgical	7,000	1	7,000
27	Projector	300	1	300
1;3	Ring stand, with base	225/12	24	450
2;3	Stopwatch	125	2	250
3	Telescope, 10X with mount	200	1	200
1;26;27	Timer	135	12	1,620
26	Test kit, fluorescent penetrant	55	24	1,320
26;27;30	Turbidimeter, Jackson candle	25	6	150
	Tubes, test, assorted sizes	45/24 sets	48 sets	90
26;27;30	Vee block	450	ass't	450
26	Pump, hydrostatic test	250	1	250
3	Rotameter	275	1	275
15	Samples, metal: iron; aluminum; copper; low-carbon steel; medium carbon steel; high-carbon steel; cast iron; alloy steel; chromium steel	10	1 each	90
26	Spectrometer, Helium mass	750	1	750
3;15	Testing machines:			
	Brinell hardness tester	10,000	1	10,000
	Dead weight tester	3,000	1	3,000
	Impact tester	5,000	1	5,000
	Rockwell hardness tester	9,500	1	9,500
	Tensile tester, universal	35,000	1	35,000
	Vickers hardness tester	8,000	1	8,000
3	Venturi tube	15	1	15
3	Hot plate with motorized stirrer	140	3	420

Estimated equipment costs based on 1979 prices.

APPENDIX F

SUGGESTED LIBRARY REFERENCES AND MATERIALS

BOOKS

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ATOMIC DATA AND NUCLEAR DATA TABLES
Academic Press, Inc.
111 Fifth Avenue
New York, NY 10003

ATOMIC ENERGY CLEARINGHOUSE
Congressional Information Bureau, Inc.
Colorado Bldg. 14th & G Streets, N.W.
Washington, DC 20005

ENERGY
Business Communications Co.
471 Glenbrook Rd.
Stamford, CT 06906

ENERGY DEVELOPMENTS
International Review Service
15 Washington Place
New York, NY 10003

ENERGY REPORTER
Federal Energy Administration
Old Post Office Bldg., Room 307b
Washington, DC 20461

HANFORD NEWS
Department of Energy
Atlantic Richfield Handford Co.
P. O. Box 250
Richland, WA 99352

HEALTH PHYSICS JOURNAL
(See Associations and Societies)
4211 39th Street, N.W.
Washington, DC 20016

INIS ATOMINDEX
UNIPUB
P. O. Box 433
Murray Hill Station
New York, NY 10016

INSTITUTION OF NUCLEAR ENGINEERS JOURNAL
(Formerly NUCLEAR ENERGY)
Institute of Nuclear Engineers
1 Penerley Rd.
London SE6 2LQ, England

NUCLEAR INDUSTRY STATUS
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR INFO
Atomic Industrial Forum
475 Park Avenue South
New York, NY 10016

NUCLEAR INSTRUMENTS AND METHODS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

OAK RIDGE NATIONAL LABORATORY REVIEW
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37830

NUCLEAR MATERIALS MANAGEMENT
Institute of Nuclear Materials Management
Seaton Hall
18 Seaton Hall
Manhattan, KS 66506

NUCLEAR NEWS
American Nuclear Society
244-a, E. Ogden Avenue
Hinsdale, IL 60521

NUCLEAR POWERPLANT PERFORMANCE
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR SAFETY
U.S. Nuclear Regulatory Commission Publication
Superintendent of Documents
Government Printing Office
Washington, DC 20402

NUCLEAR STANDARDS NEWS
American Nuclear Society
244 E. Ogden Avenue
Hinsdale, IL 60521

JOURNAL OF NUCLEAR MATERIALS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

JOURNAL OF NUCLEAR SCIENCE AND TECHNOLOGY
Atomic Energy Society of Japan
% Japan Atomic Energy Research Institute
1-13 Shimbashi, Minato-Ku
Tokyo, Japan

JOURNAL OF PHYSICS: NUCLEAR PHYSICS
Institute of Physics
47 Belgrave Square
London SWIX 8QX, England

NUCLEAR FUEL STATUS AND FORECAST
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR TECHNOLOGY
American Nuclear Society, Inc.
244 E. Ogden Avenue
Hinsdale, IL 60521

NUCLEONICS WEEK
McGraw-Hill, Inc.
1221 Avenue of Americas
New York, NY 10020

OAK RIDGE ASSOCIATED UNIVERSITIES NEWSLETTER
Oak Ridge Associated Universities, Inc.
Information Services Dept.
Box 117
Oak Ridge, TN 37830

AGENCIES, ASSOCIATIONS, AND SOCIETIES

Additional relevant materials may be obtained directly from the following sources.

AGENCIES

International Atomic Energy Agency (IAEA)

IAEA Proceedings and Directory available for purchase from its Division of Publications.

International Commission on Radiation Units and Measurements (ICRU)

International Commission of Radiological Protections (ICRP)

National Council on Radiation Protection and Measurements (NCRP)

United Nations Scientific Committee on the Effects of Atomic Radiation

United States Government

Department of Energy

Nuclear Regulatory Commission

All NRC/DOE documents are available for purchase from the National Technical Information Service of the U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151.

ASSOCIATIONS AND SOCIETIES

American Concrete Institute (ACI)

American National Standards Institute (ANSI Standards)

American Nuclear Society (ANS)

American Society of Mechanical Engineers (ASME)

ASME Boiler and Pressure Vessel Code

American Society of Quality Control (ASQC)

American Society for Testing Materials (ASTM)

American Welding Society (AWS)

Atomic Industrial Forum (AIF)

Institute of Electrical and Electronic Engineers (IEEE)

AUDIO-VISUAL AIDS

In addition to aids used by the instructor(s), there are available films and other pertinent materials showing research or production that should be available to students of nuclear technology on a selective basis. Frequently these items can be made available for equipment vendors, utility companies, Government agencies and other organizations that may be represented on a program's industrial advisory committee.

Babcock and Wilcox
Manager, Special Products & Service Marketing
Nuclear Power Generation Division
Lynchburg, VA 24505

General Electric Company
Manager - BWR Training
Mail Code 594
175 Curtner Avenue
San Jose, CA 95125

DOE - Technical Information Center
Oak Ridge National Laboratory
P. O. Box 62
Oak Ridge, TN 37830

U.S. Department of Health, Education and Welfare
Public Health Service
Bureau of Radiological Health
Rockville, MD 20852

American Society of Mechanical Engineers
Education Division
345 East 47th Street
New York, NY 10017

American Nuclear Society
555 North Kensington Avenue
La Grange Park, IL 60525

APPENDIX G

SAMPLE COSTING CALCULATIONS

SAMPLE CALCULATION NO. 1

(Two faculty members and full enrollment of students)

Assumptions:
- 24 1st-yr students.
- 16 2nd-yr students.
- 14 grads annually after 2nd yr.
- 1 Dept. head @ $24,000 - 1st yr salary.
- 1 Instructor (beginning 2nd yr) @ $18,000 - 1st yr salary.
- 1/2 Secretary @ $8,000 - 1st yr salary.
- Benefits and overhead equal to 50% of annual salaries.
- Facility modifications cost of $31,250.
- Initial capital equipment cost of $88,500 (for 1st-yr courses only).
- Additional capital equipment cost of $113,500 for 2nd-yr courses.
- Annual expendables cost of $13,000 for both 1st- and 2nd-yr courses.
- Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 31,250.00		
	Equipment	88,500.00	$ 119,750.00	
1st-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Benefits & Overhead	14,000.00		
	Expendables	6,500.00		
	Misc.	2,500.00	51,000.00	
			$ 170,750.00	$ 170,750.00
2nd-yr equipment expenditures			$ 113,500.00	
2nd-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Instructor	18,000.00		
	Benefits & Overhead	23,000.00		
	Expendables	13,000.00		
	Misc.	5,000.00	87,000.00	
			$ 200,500.00	$ 200,500.00
				$ 371,250.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 28,000	$ 47,400	$ 49,770	$ 52,260	$ 54,870
Benefits & Overhead	14,000	23,700	24,885	26,130	27,435
Equipment	10,000	25,750	25,750	25,750	25,750
Facilities	6,250	6,250	6,250	6,250	6,250
Expendables	6,500	6,500	6,500	6,500	6,500
Miscellaneous	2,500	5,000	5,000	5,000	5,000
Annual Totals	$ 67,250	$114,600	$118,155	$121,890	$125,805

*5% annual salary increase included.

SAMPLE CALCULATION NO. 2

(One faculty member and minimum enrollment.)

Assumptions:
12 1st-yr students.
8 2nd-yr students.
5 grads annually after 2nd yr.
1 Dept. head/instructor @ $20,000 - 1st-yr salary.
1/2 Secretary @ $7,000 - 1st-yr salary.
Benefits and Overhead equal to 40% of annual salaries.
Facility modification cost of $6,000.
Initial capital equipment cost of $45,000 (for 1st-yr courses only).
Additional capital equipment cost of $65,000 for 2nd-yr courses.
Annual expendables cost of $6,500 for both 1st- and 2nd-yr courses.
Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 6,000.00		
	Equipment	45,000.00		
			$ 51,000.00	
1st-yr expenditures	Dept. head	$ 20,000.00		
	Secretary	3,500.00		
	Benefits and Overhead	9,400.00		
	Expendables	3,000.00		
	Misc.	5,000.00		
			40,900.00	
			$ 91,900.00	$ 91,900.00
2nd-yr equipment expenditures			$ 65,000.00	
2nd-yr expenditures	Dept. head	$ 21,000.00		
	Secretary	3,700.00		
	Benefits and Overhead	12,250.00		
	Expendables	6,500.00		
	Misc.	5,300.00		
			48,550.00	
			$ 113,550.00	$113,550.00
				$205,450.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 23,500	$ 24,700	$ 25,935	$ 27,237	$ 28,593
Benefits and Overhead	9,400	9,880	10,374	10,892	11,437
Equipment	11,000	25,000	25,000	25,000	25,000
Facilities	1,200	1,200	1,200	1,200	1,200
Expendables	3,200	6,500	6,500	6,500	6,500
Miscellaneous	2,000	5,000	5,000	5,000	5,000
Annual Totals	$ 50,300	$ 72,280	$ 74,009	$ 75,823	$ 77,730

*5% annual salary increase included.

SAMPLE CALCULATION NO. 3

(Industrial Training Facility)

Assumptions:
- Facility diversion: $60,000
- Equipment diversion: $55,000
- On-staff instructor(s) - annual salary $28,000.
- 1/2 Secretary - annual salary $9,000.
- Benefits and Overhead - 50% of annual salaries.
- Annual expendables cost of $1,200/student.
- Miscellaneous cost of $200/student.
- 10 students/yr

Calculation:

1st-yr expenditures		
	Facility	$ 60,000.00
	Equipment	55,000.00
	Instructor	28,000.00
	Secretary	4,500.00
	Benefits and Overhead	16,250.00
	Expendables	12,000.00
	Misc.	3,000.00
		$178,750.00

NOTE: This calculation suggests costs for academic preparation only; it does not include observation, simulator training or coaching for NRC license examination.

ESTIMATED LIBRARY MATERIAL COST

Library materials for this technology, predicated on 1979 costs, may be estimated from the following:

Initial Costs	Minimum
References	$ 1,500.00
Journals	200.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.)	50.00
	$ 1,350.00

Annual Costs	
References	$ 175.00
Journals	175.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.)	50.00
	$ 500.00